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CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA.

8. *Bacillariales (Diatoms) from Griqualand West.**

By F. E. Fritsch and Florence Rich.

(Communicated by Miss E. L. Stephens.)

(With 11 figures in the Text).

The following contribution deals with the Diatoms present in the samples from Griqualand West that formed the subject of the previous paper in this series.† Not all the samples containing Diatoms have been examined in detail, but from every habitat and locality in which these forms occurred at all abundantly one or more samples have been carefully worked through. Owing to the relatively small range of habitats, referred to in the previous communication, the total number of Diatoms here recorded is small, and in that respect the aspect of the Diatom-flora agrees with that presented by the other algal constituents. In fact, in view of the great abundance of Diatoms in quite a large number of gatherings, the number of species present is surprisingly small. The total number of species here recorded is 72, of which 5 are new, while 4 new varieties are described. There are 25 new records for South Africa. It is worthy of comment that no species of *Diatoma* or *Fragilaria* were found.

The system of classification followed is that given in West and Fritsch, " British Freshwater Algae " (2nd ed., 1927).

A. CENTRICAE.

(1) *Melosiraceae.*

Genus *Melosira* Agardh.

1. *Melosira granulata*, Ehrenb.; Hustedt, Kieselalgen Deutschlands, Oesterreichs und d. Schweiz, in Rabenhorst, Kryptogamenflora, vii, 1927, p. 248, fig. 104.

* From the Botanical Department, East London College, University of London. A considerable part of this work was performed with the help of a grant from the Department of Scientific and Industrial Research made to the second author.

† Trans. Roy. Soc. S. Afr., vol. xviii, 1929, p. 1 *et seq.*

Samples 733, 749, and 750 (in all cases rare).
Diam. cell., 5–6 μ.

2. *Melosira varians*, Agardh ; Hustedt, *op. cit.*, p. 240, fig. 100.
Samples 601, 604, and 660 (rare in 604).

(2) *Coscinodiscaceae.*

Genus *Cyclotella* Kützing.

1. *Cyclotella meneghiniana*, Kütz. ; Hustedt, *op. cit.*, p. 341, fig. 174.
Samples 600, 617, 647, 656, 681, 749, 760, 821, 823, and 827 (very common in 821 and 823, rather common in 617 and 647).

The central area was either plain or very faintly punctate, with radially arranged dots. The frustules were often cohering in pairs. There was a considerable range in size ; diam., 14–35 μ.

Genus *Coscinodiscus* Ehrenb.

1. *Coscinodiscus excentricus*, Ehrenb.; Hustedt, *op. cit.*, p. 388, fig. 201 ; Van Heurck, Synops. Diat. Belg., 1880–85, p. 217, pl. cxxx, fig. 4. (Fig. nostr. 1.)

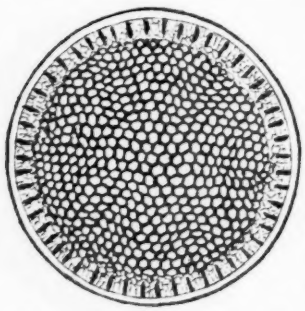

Fig. 1.—*Coscinodiscus excentricus*, Ehrenb. (× 2000).

Sample 821 (rather rare).

The specimens in 821 were all small forms (diam. 21–25 μ), agreeing closely with the figure of Van Heurck, cited above. The usually hexagonal alveoli exhibited no obvious radial arrangement, though a grouping along three rather indefinite tangential lines was to be recognised ; the largest were in the centre, the size decreasing towards the outside. The intramarginal spines were more regular than in the figures of Hustedt on p. 389 (*loc. cit.*), and were disposed at quite equal intervals. The special excentric process was not clearly recognised in any case, but it is not mentioned by Van Heurck (*loc. cit.*, p. 217), and is not to be found in one of Hustedt's figures. The presence of this marine species so far inland is noteworthy. This is a new record for South Africa.

B. PENNATAE.

(*a*) Fragilarioideae.

(1) *Tabellariaceae.*

Genus *Denticula* Kützing.

1. *Denticula* (*Grunowia*) *denticula*, Kütz.; Schönfeldt, Bacillariales, in Pascher, Süsswasserflora, x, 1913, p. 29, fig. 39.

Samples 604, 614, 618, 619, 620, 632, 656, 696, 704, 717, 728, 732, 736, 758, 760, 810, 834, 858, 868, 1354, 1356 (very common in 632, 758, and 858).

Long. cell., 17–77 μ; lat., 4–7 μ; 6–8 ribs in 10 μ; 15–18 striae in 10 μ.

In 632 and 760 the girdle-views often had slightly curved sides. New for South Africa.

(4) *Fragilariaceae.*

Genus *Synedra* Ehrenberg.

1. *Synedra acus*, Kütz.; Gemeinhardt, Die Gatt. *Synedra* in system., zytol., und ökol. Beziehung, Pflaanzenforschung, vi, 1926, p. 14; Van Heurck, *op. cit.*, p. 151, pl. xxxix, fig. 4.

Samples 614, 656, 681, 682, 726, 728, 730, 732, 760, 827, 845, 1356 (common only in 656, 681, 732, 845, and 1356).

Long. valve, 122–145 μ; lat. med., 3–4 μ. In 681, 726, and 1356 occasional individuals showed a slight constriction in the middle of the valve.

Var. *angustissima*, Grun.; Gemeinhardt, *op. cit.*, p. 16; Van Heurck, *op. cit.*, p. 151, pl. xxxix, fig. 10. (Syn.: *S. delicatissima*, W. Smith, Brit. Diatomaceae, i, 1853, p. 72, pl. xii, fig. 94.)

Sample 726 (rather rare).

2. *Synedra biceps* (Kütz.), Hustedt, Archiv. f. Hydrobiol. u. Planktonkunde, x, 1915, p. 46; Gemeinhardt, *op. cit.*, p. 12. (Syn.: *S. longissima*, W. Smith, *op. cit.*, p. 72; *S. sphaerophora*, Meister, Kieselalgen d. Schweiz, 1912, p. 73, pl. vii, fig. 5.) (Fig. nostr., 2, *R–T*.)

Samples 636, 656, 673, 681, 726, 732, 733, 736, 760, 821, 845, 871, 1356 (common only in 732 and 871).

The forms present were rather like those in Van Heurck, pl. xxxviii, fig. 3, with some indications of a rounded triangular shape at the apices (Fig. 2, *S*, *T*), and usually with a clear area at the centre of the valve, as in Meister's fig. 5 on pl. vii.

Var. *distenta* nov. var. (Fig. 2, *N–Q*).

Valvis in aspectu valvulari apices versus subito plus minus distentis, tum prope apices capitatos subtriangulares paullo contractis. Long. valv.,

212–330 μ ; lat. med., 5–6 μ ; lat. apic., 7–8 μ ; lat. inflat., 6, 5–8 μ ; striae in 10 μ, 7–8, sine area centrali.

Sample 871 (rather rare).

The characteristic feature of this variety is a rather sudden widening of the valves at a distance of about 10 μ from the capitate apices (Fig. 2, *N*). This inflation is usually separated from the latter by a more or less well-marked constriction. These peculiar forms are connected by transitions with those of *S. ulna* var. *subaequalis* described below, but there is no interruption of the striae at the centre of the valve.

3. *Synedra ulna* (Nitzsch), Ehrenb. ; Van Heurck, *op. cit.*, pl. xxxviii, fig. 7 ; Gemeinhardt, *op. cit.*, p. 6. (incl. *S. ulna* var. *aequalis*, Meister, *op. cit.*, p. 71, pl. vii, fig. 1, and *S. vitrea*, Kütz., Bacill., p. 66, pl. xiv, fig. 17).

Samples 601, 604, 632, 636, 656, 673, 681, 682, 696, 704, 709, 726, 733, 749, 821, 858, 871, 1356 (common only in 696, 704, and 1356).

We have adopted the delimitation of the type given by Gemeinhardt, and consequently have included *S. vitrea*, Kütz. ; the latter only differs in the absence of a central area which in this genus is a variable feature.

Var. *subaequalis*, Grun. ; Gemeinhardt, p. 10 ; Van Heurck, p. 151, pl. xxxviii, fig. 13. (Fig. nostr., 2, *A–F*.)

Samples 632, 636, 681, 682, 704, 705, 726, 728, 730, 732, 733, 736, 758, 822, 827, 839, 858 (common only in 636, 704, 730, 732, 758, 858).

In samples 636 and 758 some of the individuals showed practically no tapering at all, and thus come very near to *S. ulna* var. *aequalis*, Kütz., as defined by Hustedt (*loc. cit.*, 1915, p. 45 ; *cf.* Gemeinhardt, p. 11). In 730 many of the specimens showed a very slight inflation of the somewhat protruded ends (Fig. 2, *B–F*), and thus approached *S. biceps*. In 705 and 827 specimens of the *subaequalis* type occurred in radiating clusters, similar to those of var. *splendens*, Kütz., which is now regarded as synonymous with the type (*cf.* Gemeinhardt, p. 7).

Var. *subaequalis* Grun., *forma* valvis marginibus a media parte usque ad apices fere parallelis, interdum lenissime convergentibus, prope apices cum inflatione lenissima, ca. 20 μ longa, tum evidenter contractis, polis protractis marginibus parallelibus non capitatis ; striis in media parte valvarum rare interruptis. Long., 200–359 μ ; lat. 4–6 μ ; striis 9 in 10 μ (Fig. 2, *G–M*).

Samples 601, 604, 632, 656, 681, 683, 685, 700, 726, 733, 736, 827, 845, 871, 1356 (common only in 683 and 845).

The valves of this form have practically parallel margins throughout their length. A little way before the ends are reached there is a very slight inflation extending over a distance of about 20 μ, beyond which the valve is markedly narrowed and drawn out to a slender protrusion, usually with a rounded end (in 726 sometimes slightly pointed or almost conical). A few intermingled forms were just like the figure 2 on pl. vii in Meister (*op. cit.*),

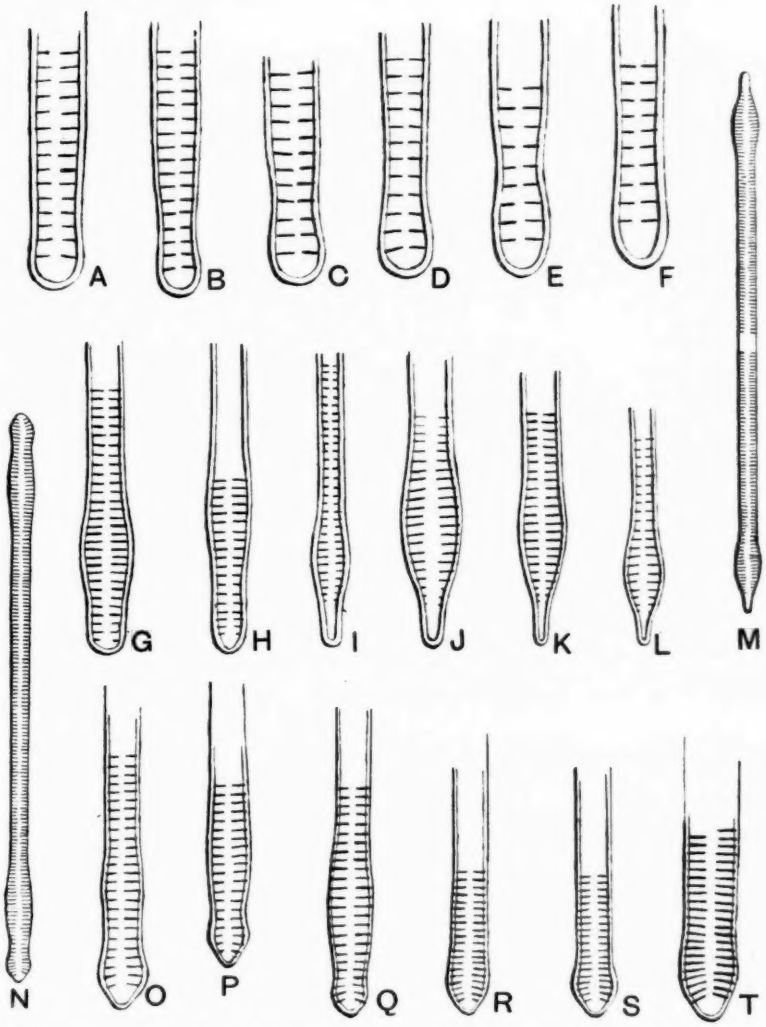

FIG. 2.—*A–F, Synedra ulna* (Nitzsch), Ehrenb. var. *subæqualis*, Grun., apices of different valves from samples 730 and 732 (all × 1300). *G–M, S. ulna* var. *subæqualis, forma* (*G–L* × 1000; *M* × 400). *N–Q, S. biceps* (Kütz.), Hustedt var. *distenta* nov. var.; *N*, complete valve; *O–Q*, various types of apices (*N* × 400; *O–Q* × 1000). *R–T, S. biceps* (Kütz.), Hustedt. (× 1000).

except that there was no clear area in the centre. In others there was a slight inflation, after which the valve continued *at the same width* as before (Fig. 2, *G*, *H*), and from these forms there were all transitions to others in which there was a more or less appreciable narrowing of the produced ends (Fig. 2, *I*, *K*). In 601, 604, and especially in 683, many of the individuals showed a more pronounced inflation, combined with a marked narrowing of the protruded ends, so that the tips had a pipette-like shape (Fig. 2, *J*, *L*, *M*). Such forms are so different from the normal type of var. *subaequalis* that one might regard them as a distinct variety or even species, but it is to be emphasised that they are connected by all transitions with the typical form. Interruption of the striae at the middle of the valve (Fig. 2, *M*) was rare.

(5) Eunotiaceae.

Genus *Eunotia* Ehrenberg.

1. *Eunotia* (*Himantidium*) *exigua*, Bréb. ; Meister, *op. cit.*, p. 81, pl. ix, fig. 9 ; Schönfeldt, Bacillariales, in Pascher, Süsswasserfl., x, 1913, p. 50, fig. 85.

Sample 728 (rather common).

Long., 12–15 μ ; lat., 3 μ. New for South Africa.

2. *Eunotia parallela*, Ehrenb. ; Meister, p. 84, pl. x, fig. 4 ; Schönfeldt, p. 45.

Sample 869 (rather rare).

Long., 80–84 μ ; lat., 10 μ. New for South Africa.

3. *Eunotia* (*Himantidium*) *pectinalis*, Kütz. ; Meister, p. 87, pl. xi, fig. 3 ; Schönfeldt, p. 50, fig. 86.

Sample 869 (very common).

Long., 20–70 μ ; lat., 8–9 μ. All the specimens had protruded, recurved, but not capitate ends. Both Meister and Schönfeldt give narrower valves, but the figure in Van Heurck (pl. xxxiii, figs. 15, 16) is nearly 10 μ wide.

(*b*) Achnanthoideae.

(1) *Achnanthaceae.*

Genus *Achnanthes* Bory.

1. *Achnanthes* (*Microneis*) *microcephala*, Kütz. ; Cleve, Synops. Naviculoid Diatoms, ii, K. Svensk. Vet.-Akad. Handl., xxvii, No. 3, 1895, p. 188 ; Meister, p. 97, pl. xii, figs. 23–26.

Samples 635, 656, 681, 730, 732, 760, 834, 1356 (common, except in 656, 730, and 732).

Long., 15–24 μ ; lat., 3–4 μ. In many cases the ends were only very slightly capitate.

2. *Achnanthes* (*Microneis*) *minutissima*, Kütz. ; Cleve, p. 188 ; Meister, p. 96, pl. xii, figs. 19, 20.

Sample 732 (rare).

Long., 9–13 μ.

Genus *Cocconeis* Ehrenberg.

1. *Cocconeis placentula*, Ehrenb. ; Cleve, *op. cit.*, ii, p. 169 ; Meister, p. 93, pl. xii, figs. 4, 5.

Sample 604 (rare).

Var. *trilineata* (Peragallo et Héribaud), Cleve, p. 169 ; Meister, p. 94, pl. xii, figs. 9, 10.

Samples 601 and 604 (rare).

Long., 21–33 μ ; lat., 11–19 μ. This variety is a new record for South Africa.

(*c*) Naviculoideae.

(1) *Naviculaceae.*

Genus *Navicula* Bory.

Section *Diploneis* Ehrenb.

1. *Navicula* (*Diploneis*) *elliptica*, Kütz. ; Cleve, *op. cit.*, i, p. 92 ; Meister, p. 104, pl. xiv, fig. 6.

Samples 636, 758, 760, and 871 (always rare).

Long., 26–40 μ ; lat., 15–16 μ ; striae, 10–11 in 10 μ.

Section *Caloneis* Cleve.

2. *Navicula* (*Caloneis*) *silicula* (Ehrenb.), Cleve, p. 51 ; Meister, p. 114, pl. xvi, fig. 10. (Syn. : *Navicula limosa*, Kütz.)

Sample 636 (very rare).

The type has not previously been recorded from South Africa.

Var. *brevistriata*, Müller, Bot. Jahrb., xliii, 1909, Beiblatt, No. 100, p. 11, pl. i, fig. 13, *forma*. (Fig. nostr. 3, *A–D.*)

Samples 601 and 604 (rare).

Long., 53–63 μ ; lat., 9–12 μ. This form has much the same shape as depicted in Müller's figure, although some individuals were slightly gibbous near the ends (Fig. 3, *B*), and others showed only a mere trace of the central inflation (Fig. 3, *C*). A broad stauros was always present (Fig. 3, *A–D*). The striae were rather longer than in Müller's figure, and were often slightly radiating near the centre of the valves (Fig. 3, *A*, *C*). These specimens

serve to link up Müller's variety with var. *ventricosa*, Cleve (*op. cit.*, p. 52 ; *N. ventricosa*, Ehrenb., Donkin, Brit. Diatomaceae, p. 74, pl. xii, fig. 7), although the striae were always shorter than in any of the published figures of that variety. Compare also *C. macloviana*, Carlson (Süsswasseralg. a.d. Antarkt., etc., Wiss. Ergebn. schwed. Südpolar-Exped. 1901–3, iv, 1913, p. 12).

Section *Naviculae orthostichae* Cleve.

3. ***Navicula ambigua***, Ehrenb. ; Cleve, *op. cit.*, p. 110 ; Meister, *op. cit.*, p. 135, pl. xx, fig. 13. (Syn. : *N. cuspidata*, Kütz., var. *ambigua*, Ehrenb.)

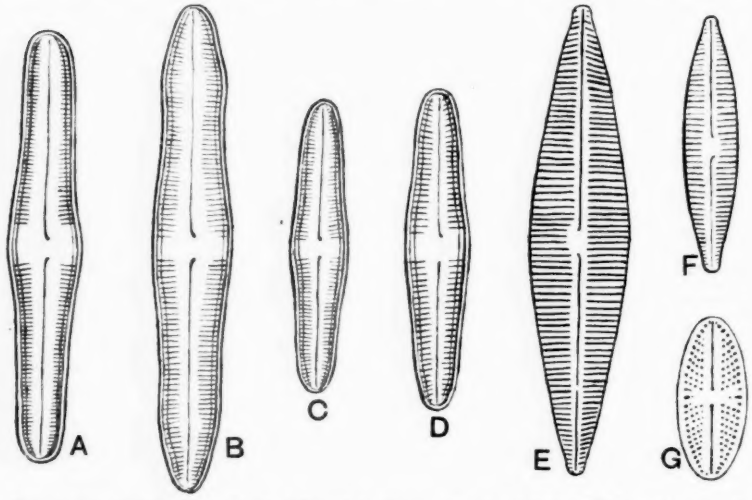

FIG. 3.—*A–D, Caloneis silicula* (Ehrenb.), Cleve, var. *brevistriata*, Müller, forma. *E, Navicula cuspidata*, Kütz., var. *lanceolata*, Grun. ; *F, N. elkab*, Müller, f. *lanceolata*, Müller. *G, N. mutica*, Kütz. var. *cohnii* (Hilse), Grun. (*A–D* × 1100 ; *E, F* × 1600 ; *G* × 1500).

Samples 601, 604, 608, 613, 614, 618, 626, 661, 696, 749, 822, 824 (common in 613, 614, 618, and 626).

Long., 68–77 μ ; lat., 17–21 μ ; striae, 14–15 in 10 μ. Craticular stages present in 696.

4. ***Navicula cuspidata***, Kütz. ; Cleve, *op. cit.*, i, p. 109 ; Van Heurck, *op. cit.*, p. 100, pl. xii, fig. 4 ; Meister, *op. cit.*, p. 134, pl. xx, figs. 10, 12.

Samples 614, 618, 619, 656, and 681 (common only in 619).

Long. cell., 58–106 μ ; lat., 14–25 μ. Craticular stages in 656.

Var. ***lanceolata***, Grun. ; Müller, Hedwigia, xxxviii, 1899, p. 310, pl. xii, fig. 18. (Fig. nostr. 3, *E*.)

Sample 635 (rare).

Rather small forms comparable to those described by Müller (*loc. cit.*), and leading over to his *N. elkab* ; long., 43–53 μ ; lat., 10 μ. The variety is a new record for South Africa.

5. *Navicula elkab*, Müller, *loc. cit.*, p. 311.

Forma *lanceolata*, Müller, pl. xii, fig. 19. (Fig. nostr. 3, *F.*)

Samples 635 (common) and 821.

Long., 24–28 μ ; lat., 5–6 μ. This form occurred in 635 side by side with *N. cuspidata*, Kütz., var. *lanceolata*, Grun., but there did not appear to be any connecting forms. The specimens were quite typical, and agreed well with Müller's figure and description.

Forma *subcapitata*, Müller, pl. xii, figs. 20–22.

Sample 734 (common).

This species is recorded for the first time from South Africa.

Section *Frustulia* Agardh.

6. *Navicula vulgaris*, Thwaites ; Cleve, *op. cit.*, i, p. 122 ; Meister, *op. cit.*, p. 121, pl. xviii, fig. 4. (Syn. : *Vanheurckia vulgaris*, Van Heurck.)

Sample 604 (in long unbranched tubes, rather common).

Section *Naviculae mesoleiae* Cleve.

7. *Navicula pupula*, Kütz. ; Cleve, *op. cit.*, i, p. 131 ; Müller, Engler Bot. Jahrb., xlv, 1910, p. 82 ; Meister, *op. cit.*, p. 130, pl. xix, fig. 25.

Samples 613, 618, 620, 656, 689, 717, 734, 749, 760, 815, 828, 834, and 871 (common only in 618 and 871).

8. *Navicula mutica*, Kütz. ; Cleve, *op. cit.*, p. 129.

Var. *cohnii* (Hilse), Grun. ; Cleve, p. 129 ; Van Heurck, *op. cit.*, p. 95, pl. x, fig. 17. (Syn. : *Stauroneis cohnii*, Hilse.) (Fig. nost. 3, *G.*)

Sample 821 (rather common).

There is considerable difference of opinion about the forms of this species. Cleve (*loc. cit.*) states under f. *cohnii*, Hilse, "valve elliptic lanceolate with rounded ends," and cites Van Heurck (*loc. cit.*). In the latter's fig. 17 are shown three individuals, two elliptic, the third (on the left) lanceolate with somewhat protruded ends. Meister (*op. cit.*, p. 128, pl. xix, fig. 14) depicts an individual of the latter type for var. *cohnii*, whilst Peragallo (Diat. marines de France, 1897–1908, pl. vii, fig. 37) draws for the type (which according to him is synonymous with *Stauroneis cohnii*, Hilse) an individual closely resembling the elliptical ones figured by Van Heurck. Both the forms mentioned differ markedly from the lanceolate shape of var. *goeppertiana*, Grun., and the ventricose one of var. *ventricosa*, Grun. Müller (Engler Bot. Jahrb., xliii, 1909, p. 15), however, refers to

var. *goeppertiana* a figure given by Grunow (Verhandl. Zool.-bot. Ges. Wien, x, 1860, pl. v, fig. 16), which would appear to be much more like var. *cohnii*.

It would seem best to restrict the name var. *cohnii* to the more or less oblong-elliptical forms, and to call the form, shown on the left in Van Heurck's fig. 17 and Meister's fig. 14, var. *subproducta* (*cf.* also Bristol, Ann. of Bot., xxxiv, 1920, p. 69, figs. 6, 7). Our specimens were typical var. *cohnii* (Fig. 3, *G*), never showing protruded apices. The individuals nearly always occurred in short chains. Long., 13–17 μ; lat., 7 μ; 15–18 striae in 10 μ.

Section *Anomoioneis* Pfitzer.

9. *Navicula sphaerophora*, Kütz.; Cleve, *op. cit.*, ii, p. 6; Smith, Brit. Diat., i, pl. xvii, fig. 148; Meister, *op. cit.*, p. 117, pl. xvii, fig. 7 (Fig. 4, *A*).

Samples 608, 613, 614, 618, 619, 647, 653, 656, 713, 760, 838, 854, 868, 869, and 871 (common in 613, 614, 618, and 871).

Long., 43–67 μ (rarely under 55); lat., 13–20 μ (usually 18). In many cases the individuals showed a very definite row of dots on either side of the median line and a complete absence of dots on one side of the valve opposite the central area (Fig. 4, *A*). This feature was never, however, constant in any one sample.

10. *Navicula exilis*, Kütz.; Cleve, *loc. cit.*, p. 8; Meister, *op. cit.*, p. 118, pl. xvii, fig. 9.

Samples 732 and 834 (rather common in the former).

Long., 19–29 μ; lat., 5–6, 5 μ.

Section *Naviculae lineolatae* Cleve.

11. *Navicula pseudo-gracilis*, Hustedt, Archiv. f. Hydrobiol., xviii, p. 244, pl. viii, fig. 4 (Fig. 4, *B*, *C*).

Samples 601, 604, and 749 (rare).

Long., 33–43 μ; lat., 7–10 μ; striae 11 in 10 μ.

We had this form described as new, when Hustedt published his species. It bears some resemblance to forms of *N. oblonga*, Kütz., and especially to var. *lanceolata*, Grun., as figured by Meister (pl. xxi, fig. 24), but the striae are quite straight throughout the valve, and do not exhibit the knee-shaped bending towards the ends of the valves which is typical of *N. oblonga* (*cf.* Cleve, ii, p. 21), and is shown in Meister's figure. The latter, however, is not much like the figure of var. *lanceolata* given by Grunow (Verhandl. Zool.-bot. Ges. Wien, x, 1860, p. 523, pl. ii, fig. 25), where the valves are more definitely lanceolate and the striae are shown straight throughout; Meister, moreover, has no striae at the ends of the valves, but such are present in Grunow's figure. The two forms can scarcely be the same.

N. pseudo-gracilis has the straight striae of Grunow's form, but the shape of the valve is different. It is also much smaller. Our forms were a little more robust than Hustedt's and with the striae a little nearer together. This is a new record for Africa.

12. *Navicula cincta*, Grun.; Cleve, *op. cit.*, ii, p. 16; Meister, *op. cit.*, p. 138, pl. xxi, fig. 6.

Samples 810, 815, and 821 (common in 810).

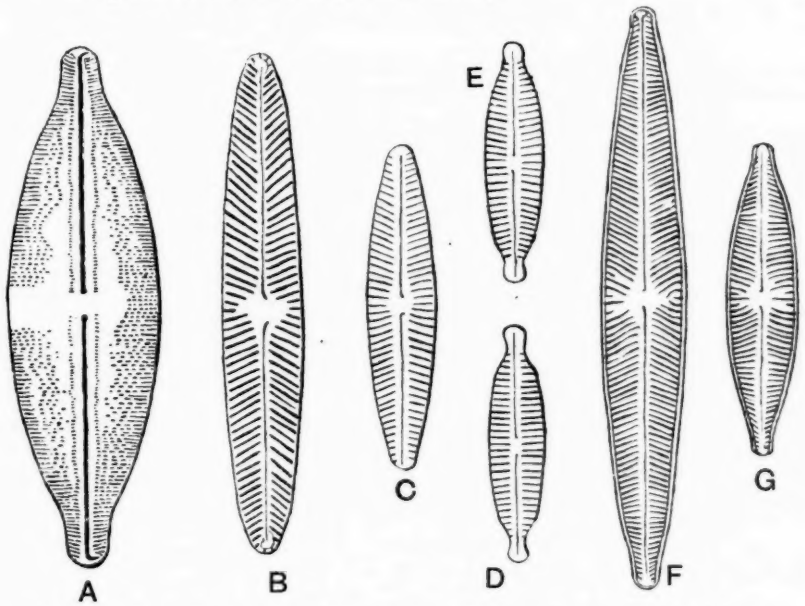

FIG. 4.—*A*, *Navicula sphærophora*, Kütz., forma. *B*, *C*, *Navicula pseudo-gracilis*, Hustedt. *D*, *E*, *N. pseudo-dicephala* n. sp. *F*, *G*, *N. vulpina*, Kütz. var. *rostrata* n. var. (*A* × 1100; *B*, *D*, *E* × 1500; *C* × 1400; *F*, *G* × 900.)

Long., 26–35 μ; lat., 5–7 μ; striae, 12 in 10 μ.

13. *Navicula cryptocephala*, Kütz.; Cleve, p. 14; Meister, p. 138, pl. xxi, fig. 3.

Samples 601, 608, 620, 642, 643, 647, 649, 661, 696, 734, 760, 821, and 834 (in the last two approaching var. *exilis*, Grun.; often rather common, abundant in 696).

Usually 22–29 μ long and 6–7 μ wide.

Var. *exilis*, Grun.; Cleve, p. 14; Meister, p. 138, pl. xxi, fig. 4.

Samples 600, 626, and 844 (common in 600).

14. *Navicula pseudo-dicephala* n. sp. (Fig. 4, *D*, *E*).

N. valvis parvis, in aspectu valvulari lateribus plus minus convexis, interdum fere subparallelis ; valvis ante polos capitatos subito constrictis ; striis distinctis, tenuibus, 16 in 10 μ, paene parallelis per totam valvam, interdum leviter radiantibus ; area mediana angustissima, area centrali exigua, rotundata ; raphe fere recta. Long., 23–25 μ ; lat., 5 μ.

Sample 834 (rather common).

This species is characterised by its shape, its parallel, delicate striae, slightly converging in the centre of the valve, and the exceedingly ill-defined central area. The raphe is only very slightly curved. It may be compared with some forms of *N. elkab*, Müller, where, however, the striae are altogether parallel, and with *N. dicephala* (Ehrenb.), W. Sm., in which the striae radiate strongly, and there is a large central area.

15. *Navicula viridula*, Kütz. ; Van Heurck, *op. cit.*, pl. viii, figs. 25, 26 ; Cleve, p. 15.

Sample 601 (rare).

Forma minor, striis centralibus alternatim brevioribus et longioribus. Long., 32–36 μ ; lat., 8–10 μ ; striae, 14–15 in 10 μ.

Sample 614 (rare).

Meister's figure (pl. xxi, fig. 10) of this species is not very typical, as the ends are not usually as markedly rostrate as he shows them (*cf.* Van Heurck, *loc. cit.*, and Schönfeldt, *op. cit.*, fig. 192).

16. *Navicula rhynchocephala*, Kütz. ; Cleve, p. 15 ; Meister, p. 139, pl. xxi, fig. 9.

Samples 601, 604, 749 (rare in 601).

17. *Navicula vulpina*, Kütz. ; Cleve, p. 15 ; Meister, p. 140, pl. xxi, fig. 15.

Var. *rostrata* n. var. (Fig. 4, *F*, *G*).

Valvis in aspectu valvulari polis leviter productis non capitatis ; striis centralibus valde radiantibus, curvatis, alternatim plus minus longioribus et brevioribus, in polis paullo convergentibus ; area mediana angusta, area centrali saepe in uno latere latiore. Formae longiores, ad 105 μ long., 16 μ lat. ; formae breviores frequentiores, 55–77 μ long., 10–15 μ lat. ; striae, 10–12 in 10 μ.

Samples 726, 760, 810, 858, 1356 (common in 760 and 858).

This variety occurs in two forms, a long slender one (Fig. 4, *F*), and a (much commoner) short squat one (Fig. 4, *G*), but the two are no doubt connected by rare intermediate forms. The ends were always somewhat rostrate, the central striae always partly long and partly short and obviously curved.

18. *Navicula lanceolata*, Kütz. ; Cleve, p. 21 ; Meister, p. 143, pl. xxii, fig. 4. (Fig. nostr. 5, *A*–*C*.)

Samples 608, 660, 661, and 749 (rare except in 661).

The material in 661 showed considerable variability in the shape of the valves. The majority of the numerous individuals had more or less pronounced subrostrate apices (Fig. 5, *A*, *C*), but a few were merely oblong-lanceolate with scarcely any protrusion at all (Fig. 5, *B* ; *cf.* Van Heurck's f. *curta*, *op. cit.*, pl. viii, fig. 17). The striae were very distinctly radiating throughout the greater part of the valve, but sometimes subparallel near the poles. In the other samples the individuals were more definitely lanceolate, but still with produced apices. This species stands very close to *N. viridula*, Kütz., in which, however, the margins of the valves are convex throughout the greater part of their length, the inward curvature leading to the rostration taking place rather near the ends of the valves.

Section *Pinnularia* Ehrenberg.

19. *Navicula* (*Pinnularia*) *wilmani* n. sp. (Fig. 5, *D*, *E*).

N. valvis subparvis, in aspectu valvulari linearibus, in media parte lenissime constrictis, quasi retusis, polis rostratis, vix capitatis, rotundatis ; striis parallelis, polos versus convergentibus ; stauros valde evolutus, saepe longior quam latior, inaequaliter ; area mediana ca. $\frac{1}{4}$ latit. valvarum. Long., 36–61 μ ; lat., 7–8, 5 μ ; striae, 12–13 in 10 μ.

This very characteristic species has linear valves, with rostrate, scarcely capitate, rounded apices ; the protrusion commences at about one-third of the length of the half-valve from the poles (Fig. 5, *D*, *E*). The middle part of the valve is very slightly drawn in, so as to create the impression of a very faint waist or of a slight retuseness. There is a very broad stauros, which is often longer than broad, and not uncommonly the striae do not start at the same level beyond the stauros on the two sides of the valve. The striae are parallel throughout the greater part of the valve, but converge somewhat at the poles ; occasionally they radiate very slightly in the middle.

The species may be compared with *Pinnularia nodosa*, Ehrenb., and *P. undulata*, Gregory, in both of which the shape of the valve is different, apart from other important distinctions.

20. *Navicula* (*Pinnularia*) *interrupta*, W. Smith, *op. cit.*, i, p. 59, pl. xix, fig. 184 ; Cleve, ii, p. 76 : Fritsch, Ann. S. Afr. Mus., ix, p. 590 *et seq.*

Forma *genuina*, Fritsch, *loc. cit.*, p. 592.

Sample 869 (rare ; long., 42 μ ; lat., 7 μ).

Forma *braunii*, Fritsch, *loc. cit.*, p. 592, fig. 40, *a*, *b*. (Syn. : *P. braunii*, Grun.) (Fig. 5, *F*, *G*.)

Sample 869 (rare).

Long., 37–48 μ ; lat., 5–7 μ. All the individuals had more or less distinctly convex sides, and more or less capitate poles (Fig. 5, *F*). In a

few the sides were very slightly retuse (Fig. 5, *G*). The striae were definitely interrupted at the middle in nearly all cases. In correspondence with the relatively small dimensions of these forms, the ribs were rather delicate.

21. *Navicula* (*Pinnularia*) *brebissonii*, Rabenh. ; Cleve, p. 78 ; Meister, p. 160, pl. xxvii, fig. 9.

Samples 601, 608, 653, 696, 749, and 760 (common, except in 601 and 749).

In 608 and 760 exceptionally large forms were encountered ; long., 39–86 μ ; lat., 10–15 μ ; costae, 11–12 in 10 μ. In 696 occasional individuals exhibited a very faint enlargement of the middle of the valve.

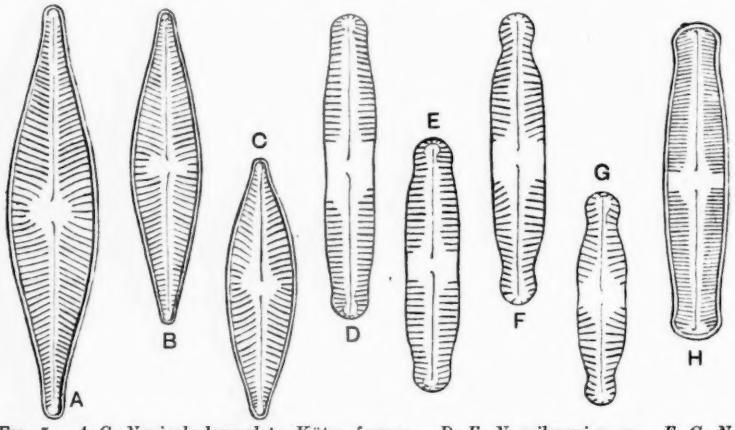

FIG. 5.—*A–C*, *Navicula lanceolata*, Kütz., formae. *D*, *E*, *N. wilmani* n. sp. *F*, *G*, *N. interrupta*, W. Smith forma *braunii*, Fritsch. *H*, *N. pseudo-stauropteroides* n. sp. (*A–C*, and *H* × 1200 ; *D–F* × 1150 ; *G* × 1100.)

22. *Navicula* (*Pinnularia*) *borealis*, Ehrenb. ; Cleve, p. 80 ; Meister, p. 158, pl. xxvii, fig. 3.

Sample 869 (very rare).

23. *Navicula* (*Pinnularia*) *viridis*, Ehrenb. ; Cleve, p. 91 ; Meister, p. 150, pl. xxiv, fig. 1.

Var. *distinguenda*, Cleve, p. 92.

Samples 636 and 871 (rare).

Long., 89–125 μ ; lat., 17–26 μ.

24. *Navicula* (*Pinnularia*) *pseudo-stauropteroides* n. sp. (Fig. 5, *H*).

N. valvis subparvis, in aspectu valvulari lineari-lanceolatis, lateribus convexis, polis leviter productis et subcapitatis, rotundatis ; costis saepe subparallelis (etiam interdum exacte parallelis), centralibus lenissime radiantibus, polos versus convergentibus, arcte dispositis et tenuibus ; stauros angustus ; area mediana angustissima, stauros versus paullo dilatata. Long., 42–53 μ ; lat., 9–10 μ ; costae, 14–16 in 10 μ.

Samples 717 and 760 (common in the first).

This species possesses a characteristic shape recalling to some extent that of *N. stauropteroides*, Fritsch (Rep. Brit. National Antarct. Exped., vi, 1912, p. 53, pl. ii, figs. 99, 100). The poles are slightly produced, rounded, and capitate. The rather delicate ribs are very closely set and almost reach the median line; they are usually quite parallel except at the ends, but in occasional individuals they are slightly radiating in the centre. In a few cases there was no stauros, and the ribs, though somewhat shorter, continued uniformly over the centre of the valve.

Genus *Stauroneis* Ehrenberg.

1. *Stauroneis anceps*, Ehrenberg; Cleve, *op. cit.*, i, p. 147; Meister, p. 123.

Samples 600 and 626 (rather common; small forms, 31–36 μ long., 8–10 μ lat.).

Genus *Gyrosigma* Hassall.

1. *Gyrosigma acuminatum*, Kütz.; Cleve, *op. cit.*, i, p. 114; Meister, p. 119.

Samples 601, 604, 608, 609, 683, 688, 696, 726, 750, 760, and 842 (common only in 601 and 750).

Usually rather small specimens (long., 87–115 μ; lat., 13–17 μ), but occasional larger ones (up to 189 μ long and 21 μ broad).

2. *Gyrosigma scalproides* (Rabenh.), Cleve, p. 118; Meister, p. 120, pl. xvii, fig. 15; Van Heurck, *op. cit.*, p. 119, pl. xxi, fig. 1.

Samples 601 and 604 (rare).

Long., 60–63 μ; lat., 9–10 μ; transverse striae clearly visible, longitudinal ones scarcely to be seen. This is a new record for South Africa.

(2) *Gomphonemaceae.*

Genus *Gomphonema* Agardh.

1. *Gomphonema constrictum*, Ehrenb.; Cleve, *op. cit.*, i, p. 186; Meister, p. 167, pl. xxviii, fig. 15.

Samples 601 and 604 (rather common in the last).

Long., 38–60 μ; lat., 10–12 μ.

2. *Gomphonema intricatum*, Kütz.; Cleve, p. 181; Van Heurck, p. 126, pl. xxiv, fig. 28. (Fig. nostr. 6, *H*, *I*.)

Samples 614, 616, 618, 632, 647, 656, 726, 736, 760, 815, 861 (never common).

Long., 34–64 μ; lat. med., 7, 5–10 μ; striae 11–12 in 10 μ. The

specimens showed the slightly dilated middle portion, with a faint concavity of the lateral margins both above and below this point (Fig. 6, *H*), which is well seen in the figure in Van Heurck (*loc. cit.*) and in Schönfeldt (*op. cit.*, p. 124, fig. 265). The striae were somewhat divergent, sometimes more so and sometimes less, in the latter case often nearly parallel (*cf.* Fig. 6, *I*). Meister (p. 169) states that the central area is transversely extended in this species, but this is scarcely marked in his figure (pl. xxix, fig. 1), nor is it shown by Van Heurck or Schönfeldt or by our specimens. In all our individuals the

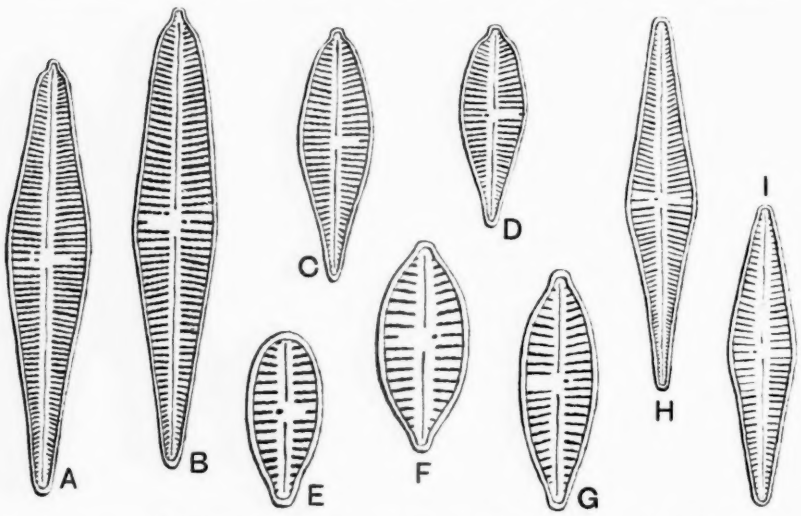

FIG. 6.—*A*, *B*, *Gomphonema subapicatum* n. sp. *C*, *D*, *G. subapicatum*, f. *curta*. *E–G*, *G. parvulum*, Grun., formae. *H*, *I*, *G. intricatum*, Kütz. (*A–D* and *H* × 1000; *E–G* × 2000; *I* × 1100).

two ends of the valves were very similar and rather narrow (Fig. 6, *H*)—much narrower than in the form figured by Meister—although the apical pole was slightly broader than the other.

3. *Gomphonema parvulum*, Grun.; Cleve, p. 180; Meister, p. 173, pl. xxix, fig. 11. (Fig. nostr. 6, *E–G*.)

Samples 604, 647, 656, 733, 734, 736, 760, 815 (only common in 647 and 734, in part intermingled with var. *micropus*, Cleve, p. 180).

In sample 733 the specimens varied somewhat in shape, many resembling var. *micropus*, Cleve, as shown by Meister (pl. xxix, fig. 12) and Van Heurck (pl. xxiv, fig. 46), with a barely perceptible constriction beneath the apex or no trace of it at all (Fig. 6, *E*; *cf.* also Van Heurck, pl. xxv, fig. 4). In others such a constriction was a little more marked, so that there was a definite,

though not very pronounced, apical protrusion, more as in fig. 11 of Meister (Van Heurck, pl. xxv, fig. 5). The latter feature was shown especially by the smaller forms. Long., 25–39 μ ; lat., 7–9 μ ; striae almost parallel.

In 734 small specimens (13–16 μ long ; 5, 5–7 μ broad) were very frequent and obviously graded over to the type (Fig. 6, *F*, *G*), and this was also the case in 604, where the majority of the individuals were again small (long., 16–22 μ ; lat., 5–6, 5 μ). It may be doubted if the var. *micropus* should be retained, as it cannot be sharply delimited from the type.

4. *Gomphonema subapicatum* n. sp. (Fig. 6, *A*, *B*).

G. valvis clavatis, latitudine maxima ca. in media parte aut paullo supra mediam partem valvae, gradatim polum apicalem versus attenuatis, polo apicali distincte apiculato, infra mediam etiam gradatim attenuatis, polo basali obtuse rotundato ; marginibus infra et supra mediam partem lenissime concavis ; striis distincte punctatis, leviter divergentibus, 10–12 in 10 μ, centralibus paullo remotioribus ; area mediana angusta ; area centrali indistincta, rotundata, utrinque stria breviore delimitata ; stigma adest. Long., 55–77 μ ; lat. med., 12–14 μ.

Samples 601, 726, 736, 740, and 749 (always rare).

This appears to be an altogether distinct species, possessing the small apiculus of *G. acuminatum*, Ehrenb. and *G. apicatum*, Ehrenb., which however have valves of an entirely different shape. Those of *G. subapicatum* are clavate, with the greatest width at the middle or slightly above the middle ; from this point there is a gradual tapering towards apex and base, the latter being bluntly rounded. The striae are distinctly punctate and slightly farther apart in the middle of the valve than elsewhere. The rather indistinct central area is bounded by shorter striae, opposite one of which is the isolated dot (stigma). The individuals appear to occur singly and not to form colonies.

f. *curta* n. f. (Fig. 6, *C*, *D*).

Latitudo maxima valvae multum supra mediam partem. Long., 28–40 μ ; lat., 10–11 μ ; striae 10–12 in 10 μ.

Samples 726, 749, 733 (rare).

These short forms approach a little more closely to *G. subapicatum*, Ehrenb.

(3) *Cymbellaceae.*

Genus *Cymbella* Agardh.

1. *Cymbella aequalis*, W. Smith, Brit. Diat., ii, p. 84 ; Cleve, *op. cit.*, i, p. 170 ; Van Heurck, p. 61, pl. iii, figs. 2, 4. (Syn. : *C. subaequalis*, Grun.) (Fig. nostr. 7, *D*.)

Sample 696 (rather common).

The specimens were small (long., 18, 5–25 μ ; lat., 5–6 μ), but very

similar to those shown in Van Heurck, pl. iii, figs. 2 and 4 (under the name *C. subaequalis*), with the dorsal surface markedly convex and the ventral one only slightly so ; the broad obtuse ends were not produced in any way. The raphe was almost straight, the median line rather narrow, but widening quite progressively towards the central area, which was scarcely marked. In many cases the central striae on either side of the valve were of unequal length. Meister (p. 189, pl. xxxii, fig. 7) depicts rather different specimens, with a slight drawing in of the dorsal margin towards either end, beyond the median convexity and striae which are practically parallel throughout and not radiating as in Van Heurck's figures. In our specimens the rather coarse striae were always distinctly radiating in the middle of the valve. It seems very probable that the forms depicted by Meister and Van Heurck belong to distinct species, ours conforming to the latter.

2. *Cymbella cistula* (Hempr.), Kirchn. ; Cleve, p. 173 ; Van Heurck, p. 64, pl. ii, figs. 12, 13 ; Meister, p. 178, pl. xxx, fig. 2. (Fig. nostr. 7, *A–C*.)

Samples 604, 636, 654, 656, 681, 683, 688, 696, 700, 726, 733, 736, 758, 760, 820, 843, 871, 1356 (common only in 700, 726, 736, 760, and 1356).

The forms of this species present in the different samples were rather variable, and in many cases one could broadly distinguish between two, viz. (*a*) a form with a practically flat ventral margin having (especially in the shorter individuals) scarcely any indications of the median convexity and mostly no indication of produced apices, although such were occasionally faintly recognisable (Fig. 7, *B*, *C*), and (*b*) a generally longer form, with a distinctly concave ventral margin and a clear median convexity (Fig. 7, *A*). Larger individuals of forma *a* were very like Van Heurck, pl. ii, fig. 12. In most samples, however, careful search showed all transitions between the two forms, although one or other usually preponderated, *a* in 726 and 1356, *b* in 760, etc. The dimensions were as follows : (*a*) long., 53–77 μ ; lat., 16–18 μ ; (*b*) long., 93–120 μ ; lat., 18–22 μ ; these are typical dimensions, the intermediate forms above referred to being often of intermediate size. In both forms isolated dots on the ventral side were variable in their occurrence, there being one, two, or three, or none at all, or they were imperfectly separated from the rows of punctae forming the central ventral striae. The type has not previously been recorded from South Africa.

3. *Cymbella helvetica*, Kütz. ; Cleve, p. 174 ; Meister, p. 180.

Var. *africana*, Fritsch and Rich, Trans. Roy. Soc. S. Afr., xi, 1924, p. 390, Fig. 30, *K*.

Sample 601 (rare).

4. *Cymbella microcephala*, Grun. ; Cleve, p. 160 ; Van Heurck, p. 63, pl. viii, fig. 36.

Sample 834 (rather common).

The specimens were very like that shown in the figure of Van Heurck,

above cited. The dorsal margin was distinctly convex, but the ventral one only very slightly convex, almost flat in some cases. The ends were markedly capitate and the striae very fine. Long., 15, 5–18 μ; lat.,

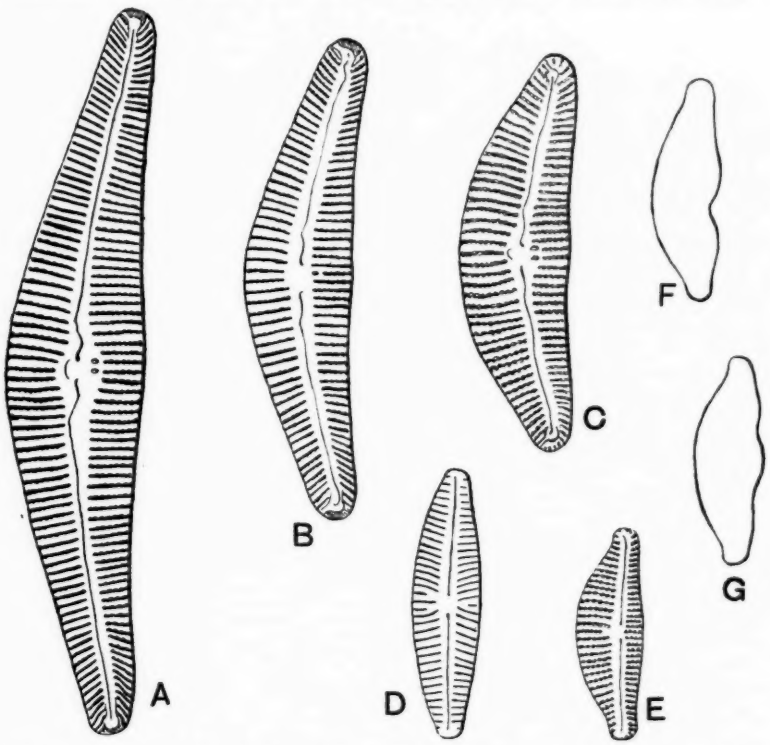

FIG. 7.—*A–C, Cymbella cistula* (Hempr.), Kirchn., formae. *D, C. æqualis*, W. Sm. *E–G, C. turgidula*, Grun.; *F* and *G*, abnormal forms. (*A–C* × 1050; *D* × 1800; *E–G* × 1000.)

3·5–4 μ. These forms are quite different from that shown in Meister, pl. xxxi, fig. 11.

This is a new record for South Africa.

5. *Cymbella turgidula*, Grun.; Cleve, p. 171; Meister, p. 178, pl. xxix, fig. 19. (Fig. nostr. 7, *E–G*.)

Samples 601, 604, 656, 681, 683, 700, 726, 733, 736, 758, 760, 810, 815, 821, 827, 843, 1354, 1356 (often common).

These were rather small forms; long., 24–39 μ; lat., 8–11 μ. The ventral surface of the valves is practically flat, with a very slight median

convexity, while the ends are rostrate and blunt (Fig. 7, *E*); on the whole very like Meister's figure. In a few individuals the two dots were not separate from the median striae. Abnormal specimens, in which the convexity on the mid-ventral surface was much exaggerated, were frequent (Fig. 7, *F*, *G*); sometimes this convexity was not exactly in the middle; sometimes there was an indentation of the ventral margin instead, either in the middle of the valve or displaced to one side. This is a new record for South Africa.

Genus *Amphora* Ehrenberg.

1. *Amphora coffeaeformis*, Agardh; Cleve, *op. cit.*, ii, p. 120; Schönfeldt, *op. cit.*, p. 143, fig. 314.

Var. *africana* nov. var. (Fig. 8, *A–D*).

Frustula in aspectu cingulari polis manifeste productis, cingulo lineis longitudinalibus distinctis praedito; valvis margine dorsali convexa, margine ventrali fere recta, polis distincte productis capitatis, leniter incurvis; parte dorsali valvarum striis punctatis, leniter divergentibus, aequidistantibus; raphe recta, marginem ventralem valde approximata; parte ventrali valvarum hyalina. Long., 21–46 μ; lat., 5–7 μ; striae, 17–19 in 10 μ.

Samples 600, 617, 624, 625, 626–8, 635, and 661 (very common in 626–8).

This variety differs from the type in the more pronouncedly capitate and produced apices to the valves and the produced ends of the girdle-view (Fig. 8, *C*, *D*). The valves have a convex dorsal margin, but a practically straight ventral margin (Fig. 8, *A*, *B*), the produced capitate apices being directed slightly inwards; the dorsal part of the valve bears slightly divergent punctate striae at equal distances along its whole length, but the ventral part is structureless. The straight raphe is very near the ventral margin. The majority of the published figures of the type are rather inadequate.

2. *Amphora lineolata*, Ehrenb.; Cleve, p. 126; Schönfeldt, p. 143, fig. 315; Van Heurck, p. 57, pl. i, fig. 23, *forma*. (Fig. nostr. 8, *E*, *F*.)

Samples 600, 601, 604, 618, 635, 644, 646, 647, 649, 650, 681, 682, 821 (common in 635, 646, 649, and 650).

The girdle-views (Fig. 8, *E*, *F*) are very characteristic. At one focus (ventral view) one sees clearly the two valves with their system of parallel punctate striae and a relatively narrow median girdle with faint longitudinal lines (Fig. 8, *E*). At another focus (dorsal view) one sees a narrow edge (valve) with short transverse striae, the wide girdle being occupied by a system of strong longitudinal lines (Fig. 8, *F*); the interspaces between these lines were transversely striated. The raphe is almost straight, but slightly bent inwards at the middle of the valves, although not as much as in the

published figures; the two ends of the raphe are remarkably far apart in the middle (Fig. 8, *E*). Long. frust., 27–42 μ; lat. frust., 13–18 μ.

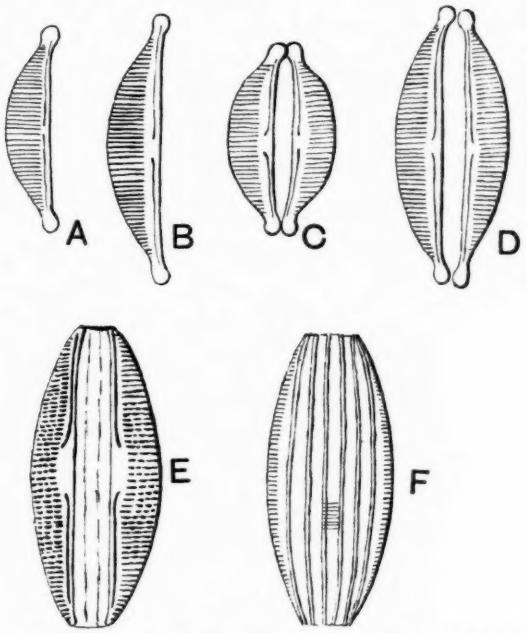

FIG. 8.—*A–D, Amphora coffeæformis*, Ag. var. *africana* nov. var. *E, F, A. lineolata*, Ehrenb. (*A–D* × 1000; *E, F* × 1760.)

Genus *Epithemia* de Brébisson.

1. *Epithemia sorex*, Kütz.; W. Smith, *op. cit.*, i, p. 13, pl. i, fig. 9; Meister, p. 197, pl. xxxiii, fig. 20.

Samples 601, 604, 634, 700, 726, 733, 734, 735, 736, 740, 749, 760, 810, 821, and 827 (rare except in 634, 726, and 740).

Long., 33–35 μ; lat., 9–10 μ.

2. *Epithemia zebra*, Kütz.; Meister, p. 199, pl. xxxv, fig. 1; Van Heurck, p. 140, pl. xxxi, fig. 9.

Samples 601, 604, 726, 733, 735, and 736 (usually rare).

Long., 42–62 μ; lat., 9–11 μ; 3–4 ribs in 10 μ. The specimens had very slightly produced ends; in fact, some showed no protrusion at all. The ventral margin of the valves was nearly straight, as in the figure of Van Heurck, cited above. The type has not previously been recorded in South Africa.

Genus *Rhopalodia* O. Müller.

1. *Rhopalodia gibba* (Ehrenb.), O. Müller, Engler Bot. Jahrb., xxii, 1895, p. 65; Meister, p. 200, pl. xxxv, fig. 6. (Syn.: *Epithemia gibba*, Kütz.)

Samples 601, 726, 733, 740, 822, 840, 842, 843, and 1356 (rather common in 601 and 840).

Individuals 117–184 μ long.

2. *Rhopalodia gibberula* (Kütz.), Müller, Hedwigia, xxxviii, 1899, p. 236; Schönfeldt, p. 148, fig. 326. (Syn.: *Epithemia gibberula*, Kütz.)

Samples 601 and 604 (rare).

Long., 30–38 μ; lat., 10–11 μ.

3. *Rhopalodia ventricosa*, Müller, Engler Bot. Jahrb., xxii, p. 65; Meister, p. 201, pl. xxxv, fig. 8. (Syn.: *Epithemia ventricosa*, Kütz.)

Samples 601, 604, 656, 726, 733, 736, 740, 749, 810, 821, 822, 836, 840, 842, 843 (common in 601, 740, and 822).

The forms of this species present graded over into *R. gibba*, and it may be doubted whether the two can really be separated. Long., 61–99 μ; lat. med., 9–11 μ.

(*d*) Nitzschioideae.

(1) *Nitzschiaceae.*

Genus *Nitzschia* Hassall.

Section *Tryblionella* Grunow.*

1. *Nitzschia tryblionella*, Hantzsch; Van Heurck, p. 171, pl. lvii, figs. 9, 10; Meister, p. 205, pl. xxxvi, fig. 6. (Syn.: *Tryblionella hantzschiana*, Grun.)

Samples 733 and 827 (rare).

Long., 87–112 μ; lat., 18–23 μ. The specimens in 733 were relatively small, and had somewhat parallel margins for a short distance in the middle of the valve, thus approaching var. *levidensis*, W. Smith.

Var. *levidensis*, W. Smith, *op. cit.*, ii, p. 89; Van Heurck, p. 171, pl. lvii, fig. 15.

Sample 681, 733, 749, 760, and 821 (always rare).

Long., 49–68 μ; lat., 13–15 μ.

* We are indebted to Dr. F. Hustedt for drawing our attention to the fact that *Nitzschia hantzschiaeformis*, Fritsch and Rich (Trans. Roy. Soc. S. Afr., xi, p. 394) is *Synedra dorsiventralis*, O. Müll.

Section *Apiculatae* Grunow.

2. *Nitzschia apiculata* (Gregory), Grun. ; Van Heurck, p. 173, pl. lviii, figs. 26, 27 ; Schönfeldt, p. 152, fig. 333.

Samples 656, 681, 749, and 827 (always rare).

The individuals of this species are like small specimens of *N. hungarica*, but with a broad and very obvious interruption of the striae and small, round, often indistinct carinal dots. The valves are clearly narrowed in the middle, the apices somewhat protruded. Long., 36–50 μ ; lat., 7–8 μ.

3. *Nitzschia hungarica*, Grun. ; Van Heurck, p. 173, pl. lviii, figs. 19–22 ; Meister, p. 206, pl. xxxvi, fig. 10.

Samples 600, 608 (lateral concavity often very shallow, and thus grading over to var. *linearis* Grun., which was also present), 614, 618, 626 (long., 69–80 μ ; lat., 8, 5 μ), 647, 656, 661, 681 (long., 51–56 μ ; lat., 6–7 μ ; dots 9–10 in 10 μ, rather small forms), 682, 696, 733, 734, 749, 760, 810, 815, and 821 (common only in 626, 696, 734, and 760).

Long., 49–96 μ ; lat., 6–8, 5 μ.

Var. *linearis*, Grun. ; Van. Heurck, pl. lviii, fig. 23.

Samples, 604, 608, 696, 733, 734, 749 (always rare).

Long., 67–118 μ ; lat., 8–8, 5 μ. The very elongate specimens were encountered in 608 and 733. There were practically all transitions to the type, as between specimens showing a marked concavity of the sides and such as had altogether straight margins.

Section *Sigmatae* Grunow.

4. *Nitzschia sigma* (Kütz.), W. Smith, Brit. Diat., i, p. 39, pl. xiii, fig. 108 ; Meister, p. 210, pl. xxxvii, fig. 10.

Var. *subcapitata*, Rabenh., Fl. Europ. Alg., i, 1864, p. 156. (Syn. : *N. clausii*, Hantzsch ; Van Heurck, pl. lxvi, fig. 10.)

Samples 749, 750, 807–818 (common in the first).

The valves usually tapered from the middle to the ends (Fig. 9, *A*), but some individuals (or only in certain positions) showed practically parallel sides in the middle and only tapered near the ends of the valves (Fig. 9, *D*, *F*). The ends are asymmetrical, one margin being practically straight, the other oblique, so that there is a rapid narrowing of the valves in this region. The actual ends are usually rounded and often somewhat capitate. Thus the whole valve appears sigmoid, but it is actually only the ends that are curved, the whole middle part being straight. In certain positions of the valves the ends appear practically symmetrical and distinctly rostrate, being appreciably narrowed down (*cf.* Fig. 9, *A*).

The girdle-view (Fig. 9, *C*, *E*) is sigmoid throughout, but not very

markedly so. It is rather narrow with blunt ends, which are narrower than the main body of the frustule. The valves were 38–73 μ long and 4, 5–6 μ wide; the carinal dots rounded, 8–10 in 10 μ, the striae very fine and hardly recognisable. Peragallo (Diat. marines de la France, pl. lxxiv, fig. 14) shows a good girdle-view, and Meister (pl. xxxviii, fig. 1) one type of valve-view (*cf.* also Fritsch, Ann. S. Afr. Mus., ix, fig. 41, *f*).

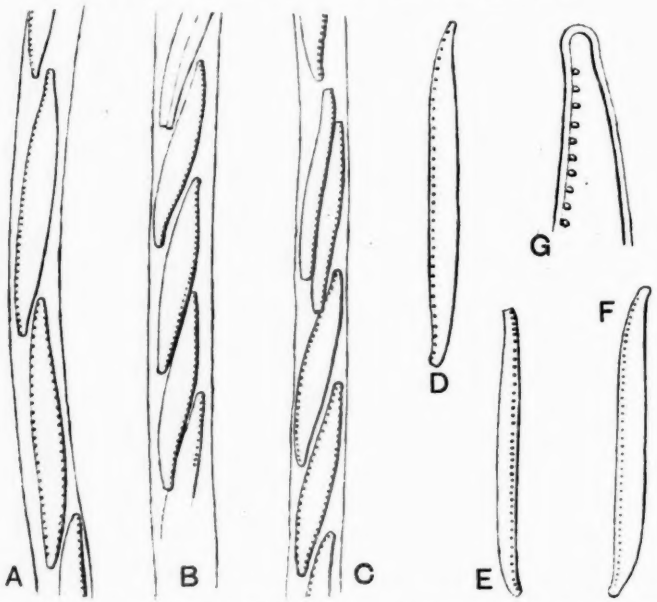

FIG. 9.—*Nitzschia sigma* (Kütz.), W. Smith, var. *subcapitata*, Rabenh. (*A–F* × 1000; *G* more highly magnified.)

In samples 749 and 750 this form occurred in long unbranched mucilage-tubes, which were in general rather narrow and sometimes not much wider than the valves; in this case the individuals were arranged in single file, usually overlapping at the ends (Fig. 9, *A*, *B*). In other cases, however, there were double rows or even more than two individuals clustered at the same level.

Nitzschia (*Homoeocladia*) *subcohaerens*, Grun., which Peragallo (*loc. cit.*, p. 292) mentions as closely related to *N. clausii*, a species in which the *Homoeocladia*-condition has not yet been recorded, would, to judge by these observations, seem to be merely a marine form of *N. sigma* (Kütz.), Sm., var. *subcapitata*, Rabenh., the only difference being that the carinal dots are more closely placed.

Section *Obtusae* Grunow.

5. *Nitzschia obtusa*, W. Smith, p. 39, pl. xiii, fig. 109.
Var. *scalpelliformis*, Grun. ; Van Heurck, p. 180, pl. lxvii, fig. 2.
Samples 810 and 815 (rare).
Long., 77–81 μ ; lat., 5, 5 μ. This is a new record for South Africa.

Section *Lineares* Grunow.

6. *Nitzschia capitata* n. sp. (Fig. 10, *C–F*).

Valvis linearibus, angustis, plerumque fere a media parte ad apices attenuatis, prope apices magis attenuatis, apicibus plus minus productis et semper levissime dilatatis, fere capitatis ; punctis carinae plerumque leviter transverse elongatis, interdum fere quadratis, medianis paullo discretis, hic margine valvarum plerumque incisione parva diverse evoluta. Frustula in aspectu cingulari rectangulari, finibus non aut leviter attenuatis, obtuse truncatis, semper incisione parva mediana utrobique hiato punctis carinae opposita ; striis tenuissimis. Long., 89–286 μ ; lat., 4–5, 5 μ ; punct. carin. 10–12 in 10 μ ; striae, 25–28 in 10 μ.

Samples 604, 608, 609, 632, 636, 653, 661, 682, 696, 733, 749, 854, 858, 868, and 871 (very common in 696, rather common in 609 and 653, otherwise rare).

The valves are rather narrow and generally commence to taper a very little way beyond the middle, but the narrowing is more pronounced towards the ends (Fig. 10, *E*). The poles always appear somewhat protruded and are invariably a little dilated at the extremity, often almost capitate (Fig. 10, *D*, *E*). The carinal dots are generally slightly drawn out in the transverse direction, being sometimes evidently elongated, sometimes nearly square ; the middle ones are always slightly separated, and at this point the corresponding margin of the valve usually shows a slight notch which varies rather in the degree of development. The girdle-view (Fig. 10, *F*) varies a little in shape, being either purely rectangular or provided with somewhat attenuated bluntly truncated extremities ; it always exhibits a slight median notch on either side opposite the gap in the carinal dots. In the girdle-view the ends of the valves appear asymmetrical (Fig. 10, *C*), as in *N. linearis* W. Sm., but in the valve-view this is not usually recognisable. The striae are very fine.

This species approaches closely to *N. linearis* (Ag.), W. Smith, but differs in the gradual attenuation of the valves from the middle towards the ends and the capitate enlargement of the latter ; also the middle carinal dots are not as widely separated as in most published figures of

N. linearis. The degree of tapering from the middle of the valves towards the ends varies somewhat, and in sample 604 some valves showed parallel sides for a short distance in the middle. In sample 661 one individual was found with altogether parallel sides, not attenuated except at the ends. This form was very much like Peragallo's figure (*op. cit.*, pl. lxxiii, fig. 11) of *N. linearis*, and showed very clearly the slight bulging of the valve opposite the gap in the carinal dots which Peragallo depicts. Such bulging was, however, also occasionally seen in specimens with tapering valves (Fig. 10, *D*).

There is some difference of opinion about the carinal dots of *N. linearis*. Schönfeldt (p. 156, fig. 345) describes and figures them as rounded, whilst Peragallo (*loc. cit.*) shows them elongated ; Meister (pl. xxxviii, fig. 4) again shows them rounded. Smith (pl. xiii, fig. 111) figures the valves of *N. tenuis*, W. Sm., a closely related form, as tapering slightly and with transversely extended carinal dots, although in *N. linearis* he shows them rounded. Van Heurck (pl. lxvii, fig. 16) shows *N. linearis* var. *tenuis* (W. Sm.), Grun. with valves tapering somewhat from the middle towards the ends, but the latter are not enlarged.

It would appear that a series of different forms are involved which grade to some extent into one another, but we have been unable to find any record of forms corresponding exactly with those here described, and have therefore thought it best to refer them to a distinct species.

7. *Nitzschia vitrea*, Norman ; Van Heurck, p. 181, pl. lxvii, fig. 10. (Fig. nostra 10, *A*, *B*.)

Samples 614, 618, 656, 681, 733, 815, and 871 (rare).

The valves are parallel-sided, with a very slight waist in the middle, and have pointed and faintly capitate ends (Fig. 10, *A*, *B*). The carinal dots are large, round, those in the middle being hardly more separated than the others. The girdle seems always to show a notch on either side. This species is near *N. recta*, Hantzsch. Long., 70–154 μ ; lat., 8–10 μ ; carinal dots, 7–8 in 10 μ ; striae in 10 μ. This is a new record for South Africa.

Section *Lanceolatae* Grunow.

8. *Nitzschia amphibia*, Grun. ; Van Heurck, p. 184, pl. lxviii, fig. 15. (Fig. nostr. 10, *J*.)

Samples 682, 730, 733, 827 (rare except in 682).

The valves were more or less parallel-sided for a short distance in the middle, but tapered sooner or later, and were narrowed strongly towards the ends, which were commonly somewhat subrostrate ; long., 17–25 μ ; lat., 4–5 μ ; carinal dots 7–9 in 10 μ, rounded and distinct. The striae were very well marked and rather far apart, about 16 in 10 μ. The girdle-view

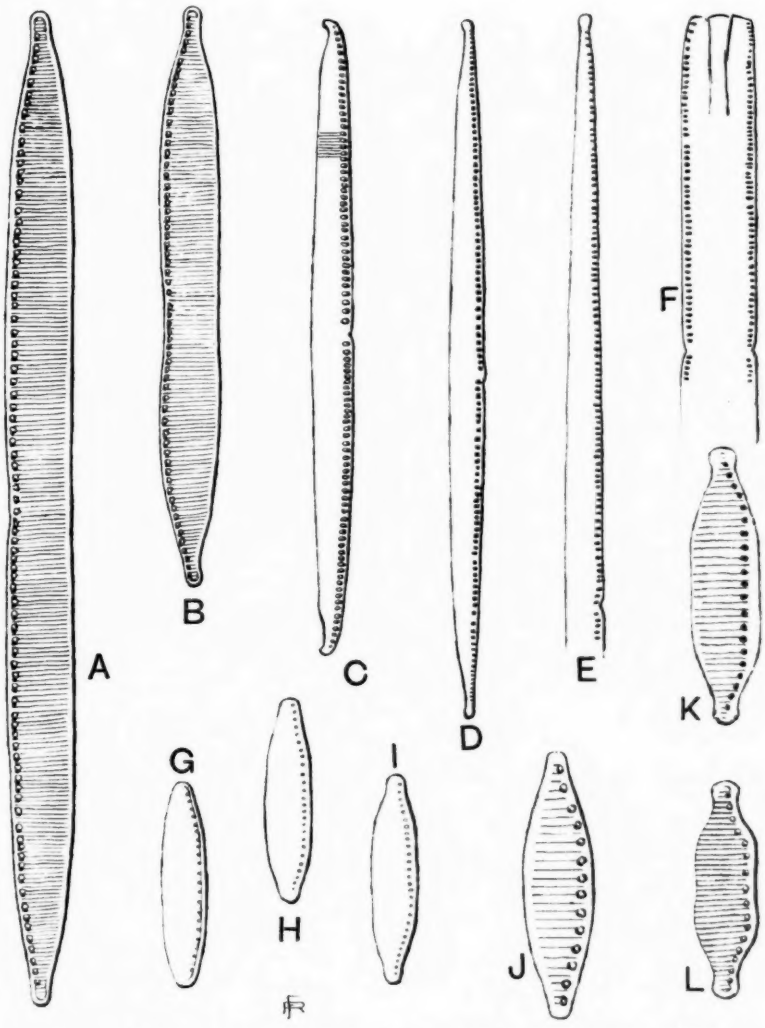

FIG. 10.—*A*, *B*, *Nitzschia vitrea*, Norman. *C–F*, *N. capitata* n. sp.; *C–E*, valves; *F*, part of girdle-view. *G–I*, *N. communis*, Rabenh. *J*, *N. amphibia*, Grun. *K*, *N. microcephala*, Grun. *L*, *N. microcephala*, Grun. var. *medio-constricta* n. var. (*A*, *B* × 1000; *G–I* × 1100; *J* × 1800; *K*, *L* × 2200.)

was distinctly rectangular, with ends of the same breadth as the rest of the frustule.

Our specimens are very much like the figure of Van Heurck, cited above, as regards the valve-view, but the girdle-view does not show the cuneate ends which he depicts and which Schönfeldt (p. 158) mentions in his diagnosis.

9. *Nitzschia communis*, Rabenhorst., Fl. Europ. Alg., i, 1864, p. 159; Meister, p. 214, pl. xxxviii, fig. 12; Van Heurck, p. 184, pl. lxix, fig. 32. (Fig. nostr. 10, *G–I*.)

Samples 656 (rare), 680–682 (usually common).

Long., 22–32 μ; lat., 5 μ; carinal dots 10–11 in 10 μ. In sample 681, where this species was very common, many of the individuals had purely oblong valves gradually tapering from the middle to the rounded-truncate ends (Fig. 10, *G*), much as in fig. 33 on pl. lxix of Van Heurck. This figure is referred to var. *obtusa*, Grun., but shows little of the subrostrate character mentioned in the diagnosis (p. 184). In other of our specimens, however, there was a slight narrowing some little way before the apices, giving a decided subrostrate appearance (Fig. 10, *H*, *I*), as in figs. 32 and 34 of Van Heurck, which are supposed to represent the type and var. *obtusa*, Grun. respectively, but scarcely show any differences. Rabenhorst (*loc. cit.*) describes the ends of the type as attenuated, as also do Meister (p. 214) and Schönfeldt (p. 158, fig. 350), but Meister's figure has far more markedly rostrate ends than any of our specimens had. His form looks more like *N. microcephala*, Grun. It may be doubted whether the type and var. *obtusa* can be separated. The carinal dots were definitely rounded in all our specimens.

Var. *abbreviata*, Grun.; Van Heurck, p. 184, pl. lxix, fig. 35.

Sample 647 (very common).

Long., 8–13 μ; lat., 3–3, 5 μ. Valves lanceolate, with pointed, slightly produced ends. The variety is a new record for South Africa.

10. *Nitzschia microcephala*, Grun.; Van Heurck, p. 183, pl. lxix, fig. 21. (Fig. nostr. 10, *K*.)

Samples 608, 618, 620, 623, 656, 733, 760, 810, and 815 (rather common in 608, 618, 760, and 810).

The valves have parallel sides, sometimes a very little drawn in, and rostrate, often somewhat capitate, apices (Fig. 10, *K*); the carinal dots are round, about 12–13 in 10 μ, the striae delicate but distinct. Long., 18–25 μ; lat., 4–4, 5 μ.

The specimens were in part rather larger than any that have to our knowledge been recorded, but the shape is so characteristic that we have no doubt about the correctness of the assignation. A very closely related, though larger, species is *N. frustulum* (Kütz.), Grun., which seems scarcely specifically distinct from *N. microcephala*, as there are all grades in the degree

of development of the capitate character of the ends of the latter. This is a new record for South Africa.

Var. *medio-constricta* n. var. (Fig. 10, *L*).

Valvis minimis, 12–17 μ long. et 3, 5–4 μ lat., in media parte evidenter constrictis, polis distincte rostratis, saepe evidenter capitatis, punctis carenae distinctis, rotundatis, ca. 10 in 10 μ ; striis distinctis.

Samples 635 (common), 815, 816 (rare).

The very small valves are distinctly retuse in the middle, although the general outline here is parallel-sided. The ends are much narrower than the main body of the valve and are very markedly rostrate ; the apices are often distinctly capitate (Fig. 10, *L*), but the degree of enlargement varies. This form is very much like the var. *elegantula*, Grun., figured by Van Heurck (pl. lxix, fig. 22 *a*), but since neither he (p. 183) nor Peragallo (p. 287) mentions the distinct median constriction and the capitate apices, we have thought it best to establish a distinct variety.

11. *Nitzschia palea*, Kütz. ; Meister, p. 213, pl. xxxviii, fig. 9 ; Van Heurck, p. 183, pl. lxix, fig. 22, *b* and *c*.

Samples 620, 632, 633, 635, 653, 656, 661, 673, 681, 682, 696, 734, 760, 810, 815, 821, and 827 (often common).

The valves are parallel-sided in the middle or very slightly tapering from the middle towards the ends ; the latter are evidently produced, but not capitate. The carinal dots are round, the striae very delicate. Long., 31–62 μ ; lat., 3, 5–5 μ ; carinal dots 11–12 in 10 μ.

Genus *Hantzschia* Grunow.

1. *Hantzschia amphioxys* (Ehrenb.), Grun., forma *capitata*, Müller, Bot. Jahrb., xliii, 1909, Beibl. No. 100, p. 34, pl. ii, fig. 26.

Samples 618, 636, 653, 821, and 869 (rare).

Long., 24–43 μ ; lat., 6–8 μ ; carinal dots, 8–9 in 10 μ.

(*e*) Surirelloideae.

(1) *Surirellaceae.*

Genus *Cymatopleura* W. Smith.

1. *Cymatopleura solea* (Bréb.), W. Smith, i, p. 36 ; Meister, p. 216 ; Müller, Engler's Bot. Jahrb., xxxiv, 1903, p. 21.

Sample 608 (rare).

Long., 107–152 μ ; lat., 28–30 μ.

Genus *Surirella* Turpin.

1. *Surirella angusta*, Kütz.; Smith, p. 34, pl. xxxi, fig. 260; Meister, p. 223, pl. xli, fig. 8. (Syn.: *S. ovalis*, Bréb. var. *angusta*, Van Heurck, p. 189, pl. lxxiii, fig. 13.) (Fig. nostr. 11, *B*.)

Samples 608, 609, and 661 (rare).

In sample 608 many of the individuals had a slight waist in the middle (Fig. 11 *B*), a character mentioned by Van Heurck. The apices were cuneate, very slightly produced, and sometimes capitate. Such forms come very close to *S. apiculata*, W. Sm., as figured by Kurz (Jahrb. St. Gall. Naturwiss. Ges., lviii, 1922, pl. i, fig. 14), but not as figured by Meister, where the production of the apices is much more pronounced. The dimensions of our specimens were: long., 32–43 μ; lat., 7–9 μ; costae 5–6 in 10 μ.

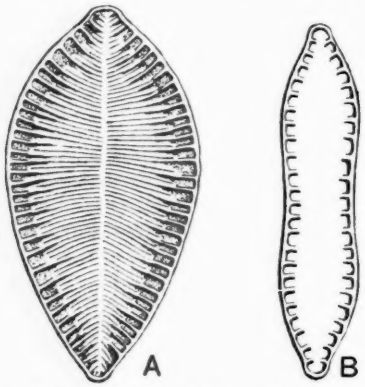

FIG. 11.—*A*, *Surirella ovalis*, Bréb., forma. *B*, *S. angusta*, Kütz. (*A* × 870; *B* × 1400).

2. *Surirella ovalis*, Bréb.; Van Heurck, p. 188, pl. lxxiii, fig. 23; Meister, p. 229, pl. xlvi, fig. 4. (Fig. nostr. 11, *A*.)

Samples 601, 604, 608, 618, 636, 647, 650, 653, 656, 673, 681, 682, 696, 709, 733, 758, 760, 810, 821, 827, and 839 (common in 653, 681, 682, and 760).

Long., 58–110 μ; lat. max., 32–52 μ.

The majority of the specimens were intermediate between figs. 3 and 4 on pl. lxxiii in Van Heurck, being more rounded at one pole than the other, with the greatest breadth of the valve about two-thirds of the length from the more pointed end. The costae were in all cases rather broad and projected inwards for a varying distance from the margin, never however penetrating far towards the middle. In 681, 682, and 827 many of the individuals were almost equally pointed at either extremity, thus resembling

more the figure given by Schönfeldt (fig. 374). Some of these even possessed a slightly protruded apical pole (Fig. 11, *A*), though not nearly as marked as in var. *apiculata*, Müll.

Var. *ovata*, Kütz. ; Van Heurck, p. 188, pl. lxxiii, figs. 5–7.

Samples 601, 604, 608, 653, 656, 681, 682, 696, 760, and 810 (common in 608 and 696).

Long., 26–53 μ ; lat., 18–28 μ ; costae, usually 4–5 in 10 μ. Under this we have included all the relatively short forms, with one end markedly broader than the other and with the costae often more widely spaced. Van Heurck shows this wider spacing in his figure, although, according to Schönfeldt (p. 170), the costae are more closely placed in var. *ovata*. There were in our samples all possible transitions between this variety and the type, both as regards the shape of the valves and the dimensions.

NOTES ON THE KARROO REPTILIA FROM MADAGASCAR.

By S. H. Haughton, B.A., D.Sc.

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(With four Text-figures.)

In Annales de Paléontologie, tome xv, fasc. ii–iv, 1926, M. Piveteau described at some length a series of reptilian remains from the Permian of Madagascar, the paper being beautifully illustrated by phototype plates. Recently, whilst on study leave in Europe, I had the opportunity of examining all the material on which Piveteau's descriptions were based, and I have reached conclusions somewhat different from those of Piveteau, which it is deemed advisable to place on record. My best thanks are due to Professor Marcelin Boule for placing facilities for work at my disposal and for permitting me to study the very fine series of Madagascar fossils in the Paris Museum.

M. Piveteau has described two species of lizard-like reptiles, and has endeavoured to trace each species through a series of growth-stages. The one he called *Hovasaurus boulei* n.g. et sp. (Piveteau, 1926) and deemed it to be closely allied to the Dwyka genus *Mesosaurus*; the other he identified as *Tangasaurus mennelli* Htn., which had been previously recorded from East Africa.

Of the two forms *Hovasaurus* is the smaller; and considering the lengths of the principal bones of the limbs only, it is possible to draw comparisons between Stages A and D of *Hovasaurus* and Stages A and B of *Tangasaurus* respectively. This fact will be used subsequently. It is proposed first to consider details of the various specimens assigned to *Tangasaurus*.

Tangasaurus mennelli.—In addition to the specimens from Madagascar, we can place the two individuals from East Africa in Piveteau's sequence. On the basis of limb-length, the smaller specimen from Tanga comes between Piveteau's Stages C and D, and the larger specimen between Stages D and E. We obtain then a sequence of forms having humeri varying in length from 10·5 mm. to 53 mm., and femora varying from 14 mm. in length to 53 mm. The ratio between humeral and femoral length is not constant, but—as the following table shows—there is a constant

increase in the ratio with approaching maturity. This can presumably be accounted for by the retarded ossification of the epiphyses of the humerus when compared with the conditions of the femur in the same stage.

	Humeral length (H).	Femoral length (F).	Ratio: $\frac{H}{F}$.
	mm.	mm.	
Stage A	10·5	14·0	0·75
,, B	15·0	20·0	0·75
,, C	22·0	26·5	0·83
Small specimen from Tanga	36·0	39·0	0·92
Stage D	?	42·0	?
Large specimen from Tanga	47·0	47·0	1·00
Stage E	53·0	less than 53·0	1·00+

Stage A.—To Piveteau's description there is little to add. The humerus is 10·5 mm. long, the radius 6·5 mm., the femur 14·0 mm. long, and the tibia 13·0 mm. The humerus has dilated ends, the planes of expansion of the two ends being at right angles to one another. Even at this young stage the intermedium, fibulare, and what is probably the tibiale are ossified; but none of the bones of the carpus are formed. The proximal end of the 5th metatarsal is wider than that of the others. The digital formula of the pes is definitely 23454.

Stage B.—At this stage the humerus is 15 mm. long, the radius 11 mm., the femur 20 mm., and the tibia 18·5 mm. The distal portion of the humerus is expanded and shows an entepicondylar foramen. The carpus is almost unossified. The formula of the hand is 23453 and not as Piveteau gives it. The 3rd phalanx on the 5th digit is undoubtedly the final claw. The longest digit is 22 mm. long.

At this stage, too, there are two small sternal plates. I also identify the pubes and ischia, which are similar here to those of *Hovasaurus.*

In the tarsus, the fibulare, intermedium, tibiale (?), and two tarsalia are ossified. Metatarsals I–V have the following lengths: 4·2 mm., 7·2 mm., 9·0 mm., 9·8 mm., and 7·2 mm. The 4th digit is 33 mm. long. The 5th metatarsal is expanded proximally to a greater extent than the others.

Stage C.—The lengths of the principal limb-bones at this stage are: humerus 22 mm., radius 14·5 mm., femur 26·5 mm., tibia 23·5 mm. As Piveteau has pointed out, the ribs are somewhat swollen distally, and there is a development of abdominal ribs. The coracoids are elongate oval with a coracoid foramen; the two sternal plates are separated by the long interclavicle and are rounded and somewhat elongate with slightly concave

posterior external borders. The humerus has a large internal distal condyle and an entepicondylar foramen. The carpus is fairly fully ossified and consists of ten bones, of which the largest are the ulnare and intermedium. There are a small radiale, two centralia, and five carpalia, of which the fourth articulates with both the 4th and 5th metacarpals. The digital formula of the hand is again 23453, as can be easily observed by a study of Piveteau's pl. v. The 3rd digit has a length of 22·5 mm., the 4th of 27 mm.

The pubis has an antero-lateral ventral spinous protuberance, and a pubic foramen. In the tarsus, the fibulare and intermedium are both large, but the former has no definite heel. The tibiale is small : the 4th tarsal is much larger than the others and articulates with the 4th and 5th metatarsals. Of the metatarsals, the 5th is the most robust.

Small Specimen from Tanga.—The dimensions at this stage have been given in the original description (Quart. Journ. Geol. Soc., lxxx, 1924, pp. 2 *et seq.*). Here the sternum is formed of a single rounded plate which touches the elongate coracoids anteriorly. The humerus has an entepicondylar foramen. The digital formula of the hand is 23453 ; the 5th metacarpal is stout. The tarsus is well ossified, the intermedium and fibulare articulating with one another and having a foramen between them. As in Stage C, the 4th tarsal bone is large and articulates with the 4th and 5th metatarsals.

Stage D.—This is only represented by a single incomplete specimen. The fibulare and intermedium can be seen in the pes. I am unable to agree that the fifth finger of the hand has four digits ; reference to Piveteau's figure shows that the final phalanx is undoubtedly a claw and that the digital formula must have been 23453. The broad high neurapophyses of the mid-dorsal vertebrae are well displayed.

It is interesting to note that on the slab containing the figured specimen there is preserved the impression of a large frond of *Glossopteris* sp.

Large Specimen from Tanga.—Here the femur is of the same length as the humerus. The coracoids are large and elongate and have a coracoidal foramen. There is a large single sternum and a long interclavicle with a rhomboidal head. In the foot the 4th metatarsal is longer than the 3rd, and the 5th metatarsal is of much stouter build than the others.

Stage E.—This is represented in the Paris Museum collection by several specimens. One of these displays the palatal view of the back part of the skull. Piveteau has described it fully, but somewhat erroneously, and in his description (p. 75) he has attributed to the present writer certain views as to the connection between *Tangasaurus* and *Euparkeria* which have certainly never been held nor expressed.

As Piveteau has mentioned, the basisphenoid with its lateral tubera and median vault and the rostrum-like parasphenoid bar are well displayed

(see pl. ix, fig. 1, *loc. cit.*). On either side of the basisphenoid, at the level of the back of the median keel, are two short processes with expanded distal ends which I identify as basipterygoid processes. As seen on the right-hand side in Piveteau's fig. 1 of pl. ix, this basipterygoid process articulates with the pterygoid—a long plate-like bone with two lateral ridges and a low median vault. The pterygoid undoubtedly carried teeth.

The bone which Piveteau discusses as a possible basipterygoid process and dismisses because it arises from the parasphenoid is, in all probability, a crushed epipterygoid articulating above with the parietal.

(*Note.*—The plate-references given in the following notes are to the plates in Piveteau's paper.)

Although in pl. ix, fig. 1, the interclavicle only penetrates half-way along the sternal plate, in pl. ix, fig. 3, it passes to the hinder end of the plate. The sternal plate is here single, rhomboidal, and could have been formed by the coalition of two plates; but it is to be noted that no known specimen shows the commencement of such a coalition.

In pl. viii, fig. 1, the humerus is 53 mm. long and the femur—which is slightly incomplete—was of the same length or slightly shorter. The tibia was about 50 mm. long. The tarsus consists of a large intermedium and a large rounded fibulare with a slight heel, a smaller tibiale, and four tarsalia, of which the fourth is much larger than the others. The metatarsals have the following lengths: I, 12 mm.; II, 20 mm.; III, 24 mm.; IV, 24·5 mm.; V, 20 mm.

In pl. ix, fig. 3, the humerus is 53·5 mm. long and shows a pronounced entepicondylar foramen.

In pl. xi, fig. 1, where the femur is about 50 mm. long, the tarsus has a fibulare with a slight heel. The lengths of the bones of the pes in this specimen are:

No. of digit:	I.	II.	III.	IV.	V.
	mm.	mm.	mm.	mm.	mm.
Metatarsal .	10·0	17·5	20·0	21·0	17·0
Phalanx 1 .	9·0	8·0	10·0	11·0	12·5
,, 2 .	?	8·0	7·0	7·0	8·0
,, 3 .	..	6·0	7·5	7·0	8·0
,, 4 .	..	..	?	7·5	5·0
,, 5 .	..	..	..	5·0	..

In pl. x, fig. 4, the hand obviously has a formula 23453. The radius is 31·5 mm. long. The lengths of the bones of the manus are as follows:—

No. of digit :	I.	II.	III.	IV.	V.
	mm.	mm.	mm.	mm.	mm.
Metacarpal .	6·0	8·5	10·0	10·5	7·5
Phalanx 1 .	6·5	5·5	6·0	6·5	6·5
,, 2 .	6·5	6·0	6·0	6·0	6·5
,, 3 .	..	5·5	5·5	5·5	5·5
,, 4 .	..	..	6·0	6·0	..
,, 5 .	..	..	..	4·5	..

We have thus a series of forms at various stages of growth from which most of the details of structure of the skeleton can be discerned. Amending Piveteau's description in the light of newer observations, we may diagnose the species *Tangasaurus mennelli* as follows : " Head triangular, neck short, body comparatively short, tail long, limbs lacertiform, hind limb longer than front. Basisphenoid with lateral ridges and tubera, parasphenoidal rostrum, definite basipterygoid processes, pterygoids plate-like, dentigerous, not very widely separated. Vertebrae notochordal, amphicoelous, with strong neural spines. Twenty-four presacral and two sacral vertebrae. No presacral intercentra seen. Ribs single-headed, but approaching the double-headed state in the mid-dorsal region. Ventral armour of abdominal ribs.

" Clavicles strong, rib-like ; interclavicle long with rhomboidal head. Single elongate coracoid with coracoid foramen. Sternum of two separate plates in juvenile stages, but of one large central plate in adult. Humerus with expanded ends, twisted, strong deltoid crest, large inner distal condyle, large entepicondylar foramen. Humerus increases in length more rapidly than femur, so that in adult stage it is at least equal in length to the femur. Radius and ulna much shorter than humerus. Carpus consisting of large ulnare and intermedium, small radiale and pisiforme, two centralia, and five carpalia, of which the fourth is the largest. Carpus largely cartilaginous in young stages, gradually ossifying, the pisiforme and 5th carpal being the last bones to ossify. 5th metacarpal short but stout. Phalangeal formula 23453. Ilium extended both anteriorly and posteriorly. Pubis and ischium plate-like with a median pubo-ischiac vacuity. Pubis with anterior border bent downwards and furnished with a strong ventral spinous protuberance. Pubic foramen well developed. Femur slender, sigmoidal. Tibia nearly as long as femur. Tarsus formed of large intermedium and fibulare, small tibiale and four tarsalia of which the fourth is the largest. Fibulare with slight heel. Tarsus ossified in juvenile stages. 5th metatarsal strong but without a proximal spur. Phalangeal formula 23454."

Before discussing the affinities of this form it will be advisable to describe briefly the remains of *Hovasaurus boulei*.

HOVASAURUS BOULEI.—In his description, Piveteau has again discussed the features of five growth-stages, lettered A to E. The final stage is of a much smaller animal than the final stage of *Tangasaurus*, but in the initial Stage A the two animals are of approximately the same size.

Stage A.—In the figured specimen there is preserved a portion of the hinder part of the skull, which was overlooked by Piveteau. The neck was thus very short. There are no dorsal intercentra. The ribs are not swollen, except to a slight extent distally. The abdominal ribs well developed. The humerus is 12 mm. long ; its ends are not ossified. Carpus is entirely unossified. The coracoid is rounded with a coracoid foramen. Clavicles and long interclavicle present. Pubis and ischium both visible, preserved as rounded plate-like bones. The hind leg is longer than the front limb. Of the tarsus, the intermedium and fibulare are ossified as small rounded bones. The 5th metatarsal is considerably stouter than the others.

Stage B.—In the figured specimen the femur is 16 mm. and the tibia 14 mm. long. The sternal plates are round and slightly elongate. One bone of the carpus seems to have been ossified. The hand is much shorter than the foot. In the tarsus the intermedium, fibulare, and 4th tarsal are preserved. Phalangeal formula of pes 23454. Pubis and ischium similar to those of *Tangasaurus*, former with the anterior ventral protuberance.

The feet are well seen in a slightly larger specimen, where the femur is 17 mm. and the tibia is 16 mm. long. Here a tiny intermedium is ossified in the carpus, and the digital formula of the hand is 23453.

Stage C.—A portion of the head is preserved. The orbits were apparently large and the interorbital bar narrow, but broadening considerably in the region of the postorbital bar. There are two temporal openings on each side, of which the upper are smaller than the lower. The neck is short.

Stage D.—In the specimen figured on pl. iv, fig. 4, the femur is 20 mm. long. In that on pl. iii, fig. 1, it is 21 mm. long and the tibia is 18 mm. long. There are three bones ossified in the tarsus (intermedium, fibulare, and 4th tarsal) and one small bone in the carpus. The distal extremity of the ribs is not greatly enlarged. The sternal plates are rounded and slightly elongate. There is a large pubo-ischiadic vacuity in the pelvis, and the pubis has its anterior border bent down and furnished with a blunt spine. In this specimen, too, there is a long interclavicle which was not recognised by Piveteau ; it has been displaced, and lies to the side of the sternal plates and not between them.

In one specimen where the femur is 21 mm. long, the humerus is 17 mm. in length and the radius 12 mm. The humerus is, however, a much stouter bone than the femur. This slab, too, shows the metatarsals which have the

following lengths: I, 3·8 mm.; II, 7·3 mm.; III, 8·0 mm.; IV, 8·3 mm.; V, 6·5 mm; while the length of the 3rd digit is 21·5 mm. In a specimen where the humerus is 18 mm. long, the carpus is not ossified, and the longest digit of the hand is 17·5 mm. long.

Stage E.—This represents the largest specimen which Piveteau has assigned to *Hovasaurus*. The scapula has a short broad blade; the coracoid is oval but not elongate; the sternal plates are separate and oval; the clavicles are rib-like bones, the interclavicle long and T-shaped. The humerus is similar to that of *Tangasaurus* with a prominent deltoid crest and an entepicondylar foramen. There is, however, a considerable gap between the distal end of the humerus and the bones of the lower arm, and it seems doubtful whether this stage of *Hovasaurus* represents as adult an animal as Stage E of *Tangasaurus*.

It is interesting to note that, although the remains of *Hovasaurus* occur mainly in banded nodules in a fine-grained banded sandy shale, or as imprints in fragments of banded sandy shale, the belly in every case contains a mass of large and small quartz pebbles. These sometimes extend to just behind the pelvis, but, except in one case, none occur in front of the abdomen or in the thorax. On the other hand, except for one or two examples which contain a few pebbles, the specimens of *Tangasaurus* do not display this feature. These masses of pebbles can only be interpreted as gastroliths.

Comparison between Hovasaurus and Tangasaurus.

Piveteau has placed *Hovasaurus* in the Order Ichthyopterygia, Sub-order Mesosauria, and the genus *Tangasaurus* in the Araeoscelia or Protorosauria. Nopcsa, basing his classification on the description of the specimens from Tanga alone, has also placed *Tangasaurus* in the Order Araeoscelia.

Leaving aside for the moment the consideration of the skull structure—which in both genera is open to some doubt—it is possible to draw up interesting lists of similarities and differences between the two genera. Using the length of femur as a basis, we can presume that Stage A and Stage D of *Hovasaurus* are of approximately the same maturity respectively as Stage A and Stage B of *Tangasaurus*; and it is possible that Stage E of *Hovasaurus* has not yet reached the maturity of the smaller skeleton of *Tangasaurus* from Tanga.

We obtain, then, the following similarities:—

1. Neck fairly short.

2. Shoulder-girdle composed of scapula, single coracoidal bone with coracoid foramen, rib-like clavicles, long interclavicle with rhomboidal head, and two oval sternal plates which, certainly in *Tangasaurus* and probably in *Hovasaurus*, coalesce into a single plate at maturity.

3. Humerus twisted, with strong deltoid crest, with expanded distal end and entepicondylar foramen.

4. Phalangeal formula of hand 23453.

5. Ribs slightly enlarged distally.

6. Ventral armour of abdominal ribs.

7. Pelvis of three elements. Pubis plate-like, with anterior edge bent down and carrying pronounced blunt anterior ventral spine ; pubic foramen. Ischium plate-like, with concave postero-lateral border. A pubo-ischiadic vacuity.

8. Femur sigmoidal, slightly longer than tibia.

9. Phalangeal formula of pes 23454.

10. Tail long. Chevrons large.

11. Dorsal vertebrae with strong broad neural spines, and no intercentra.

The two forms seem to differ from each other in the following details of their post-cranial skeleton :—

12. *Hovasaurus* has a rounded coracoid instead of the elongate bone of *Tangasaurus*.

13. The body of *Hovasaurus* is comparatively longer, or the limbs are comparatively shorter.

14. The ossification of the carpus of *Hovasaurus* is somewhat retarded, and the hand is reduced in length.

15. In *Hovasaurus*, as a consequence of the reduction of the hand, the fore-limb is comparatively shorter.

16. Ossification of the tarsus somewhat retarded in *Hovasaurus*.

17. Abundant gastroliths in *Hovasaurus*.

These points of difference are to be considered as specialisations for a more aquatic mode of life in *Hovasaurus*, and can be reduced to features connected with an elongation of the body and reduction of the fore-limb and its associated muscles ; they can scarcely discount the more numerous and more fundamental points of similarity displayed by the two genera.

It remains to consider the fragmentary evidence offered by the known skull remains. The two Orders Ichthyopterygia and Araeoscelia, into which the two genera have hitherto been placed, are characterised by the presence of a single temporal vacuity. The temporal region of *Tangasaurus* is unknown, and that of *Hovasaurus* known only from the specimen figured by Piveteau on pl. ii, fig. 3. Here it can be seen that the parietal is broader than the frontal, that the orbit is large, that there are *two* temporal openings on the left side of the skull and not one as has been supposed for both genera, and that in all probability there is a small pineal foramen. *Hovasaurus* is thus a Diapsid reptile ; and in view of the close affinities between the post-cranial skeletons of the two genera, it is concluded here that *Tangasaurus* is also a Diapsid.

Assuming, therefore, that these two genera are allied, and that both are Diapsids, interesting comparisons can be drawn with certain of the described forms from South Africa.

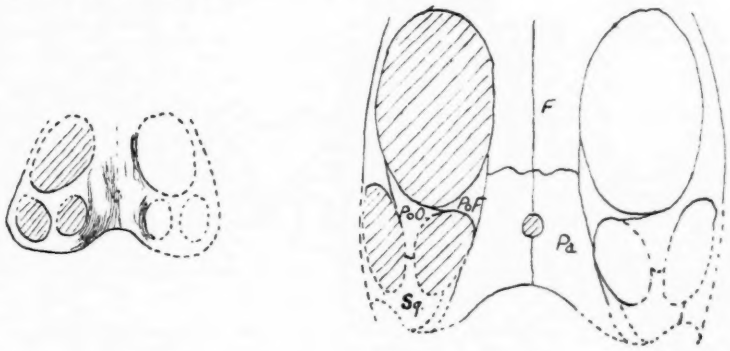


FIG. 1.—A. Dorsal view of back part of skull of *Hovasaurus boulei* (Stage C). B. Dorsal view of back part of skull of *Palaeagama vielhaueri* (after Broom).

COMPARISON WITH OTHER KNOWN FORMS.

Youngina.—One of the earliest known Diapsids is *Youngina capensis*. It has a broad parietal region like that of *Hovasaurus*, with a larger pineal foramen. Its shoulder-girdle is imperfectly known, but it, too, had a single coracoid and two sternal plates. Its humerus is of the type seen in the Madagascar forms, with a strong deltoid crest, expanded inner distal condyle, and entepicondylar foramen. The pubis is imperfectly known, but apparently is of similar form. The tarsus of *Youngina* differs from that of *Tangasaurus* in having a slightly more developed heel on the fibulare, and in the retention of the 5th tarsal. The 5th metatarsal in both genera has an expended proximal end, and probably articulated with the fibulare by means of cartilage. (In these respects the *Tangasaurus* tarsus approaches closely that of *Galechirus scholtzi*, whilst the carpus is also similar in structure to the *Dromasaurian* carpus.)

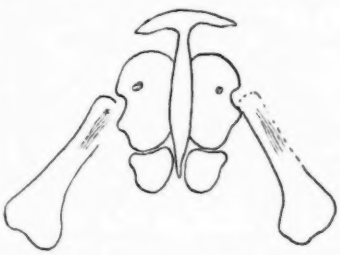


FIG. 2.—Coracoids, sternal plates, interclavicle, and humeri of type of *Saurosternon baini* in British Museum.

Saurosternon baini.—The type and only described specimen of this is in the British Museum. Nopcsa has already (1924) allied it with *Tanga-*

saurus in a single family. I have recently had an opportunity of examining the type, and give some drawings and measurements of it. No portion of the head is preserved. In the shoulder-girdle both coracoids, the interclavicle and the two sternal plates are preserved. The coracoid is 9·5 mm. long, is of the same shape as that of *Tangasaurus*, and has a coracoid foramen. The interclavicle is 20 mm. long and has a broadened rhomboid head with

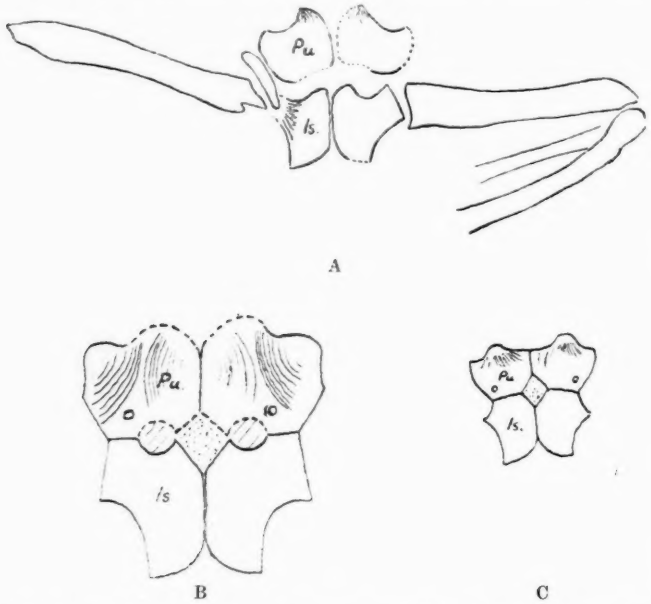


FIG. 3.—Pelvic plate of : A. Type of *Saurosternon baini*. B. *Palaeagama vielhaueri* (after Broom). C. *Hovasaurus boulei* (Stage D).

clavicular spurs. The sternal plates are 6·5 mm. long and almost touch the posterior borders of the coracoids.

The humerus, as Nopcsa has pointed out, is robust and has an expanded distal end. It is 17 mm. long. The proximal end had its longest plane at right angles to that of the distal end and was probably furnished with a deltoid crest. The inner distal condyle is more expanded than the other and there was probably an entepicondylar foramen. The breadth at the distal end is 6·5 mm. The radius is 12 mm. long.

The pubis and ischia are both displayed, while the ilium can be seen to have at least an anterior prolongation. The pubis is plate-like, with its anterior border similar to that of *Hovasaurus*. The ischium is plate-like, its

postero-lateral border concave, and its anterior border notched as if denoting the presence of a large obturator foramen. There is also a small rhomboid pubo-ischiadic vacuity.

The femur is 23·5 mm. long, slightly sigmoidal and slender. The tibia is 21 mm. long. The tarsus consists of an intermedium and a fibulare with a slight heel in the proximal row, a broad tibiale lying distal to the intermedium, and five tarsalia of which the fourth is the largest and the fifth small. The metatarsals have the following lengths: II, 6 mm.; III, 10 mm.; IV, 9·5 mm.; V, 5 mm. The fifth is stouter than the others, but of primitive type.

The ribs are fairly long and, doubtfully, single-headed. There is an

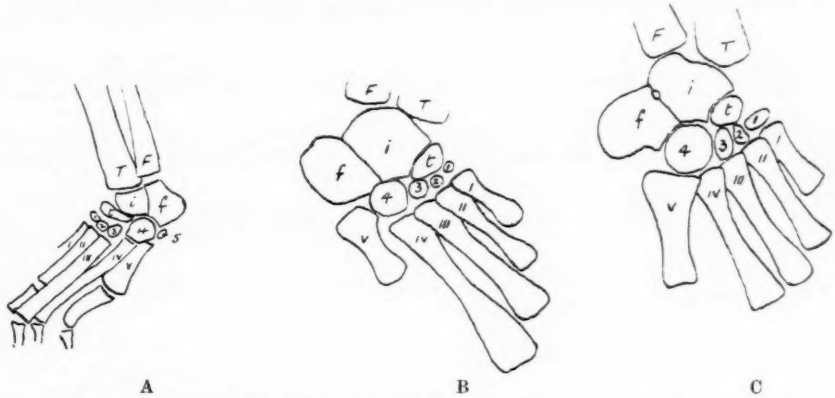


FIG. 4.—Tarsus and metatarsus of: A. Type of *Saurosternon baini*. B. *Palaeagama vielhaueri* (after Broom). C. *Tangasaurus mennelli* (Stage E).

armour of abdominal ribs and possibly small abdominal scutes are present. The first four caudal vertebrae have long transverse processes.

Apart from the 5th tarsal and the obturator foramen, *Saurosternon baini* shows numerous points of similarity with *Tangasaurus* and *Hovasaurus*.

Palaeagama vielhaueri.—Another Eosuchian with which comparisons may be made is *Palaeagama vielhaueri*, recently (1926) described by Broom. In the large orbit, possession of two temporal openings, and the broad parietal *Palaeagama* recalls the skull features of *Hovasaurus*. In the possession of two sternal plates, the nature of the humerus, the comparative slenderness and size of radius, femur, and tibia, and the structure of the tarsus, it also resembles *Hovasaurus*. It differs from the Madagascar forms in having dorsal intercentra and an obturator foramen, although in other respects than the last the pubis and ischium is the same in all three genera. The obturator foramen is also featured by *Saurosternon baini*.

Consideration of all these forms thus leads to the following definition :—

Order EOSUCHIA. Broad parietal arch. Two temporal openings, an upper and a lower. Single coracoid with coracoid foramen. Interclavicle present. Sternal plates or plate present. Humerus twisted, with deltoid crest, expanded distal end and entepicondylar foramen. Phalangeal formula of manus 23453. Plate-like pelvis with pubo-ischiadic vacuity. Femur sigmoidal, femur and tibia long and slender. Phalangeal formula of foot 23454. Intercentra present or absent.

Within this Order it seems possible to trace certain lines of descent from *Youngina*, the earliest of the forms. One line consists of those forms in which an obturator foramen has been developed, the other in which it is not present. In the first line *Saurosternon* is more primitive than *Palaeagama* in that it retains the 5th tarsal ; in the other *Tangasaurus* is an advance on *Youngina* in that it has lost the 5th tarsal, whilst *Hovasaurus*, with its reduced fore-limb and coracoid, retarded ossification and elongate body, represents a line of aquatic specialisation. *Saurosternon* is certainly intermediate in age between *Youngina* and *Palaeagama* ; and therefore we would seem to be justified in considering *Tangasaurus* as a more recent form than *Youngina* and to place the beds containing it in the Upper Permian or Lower Trias.

COLOUR AND CHEMICAL CONSTITUTION.

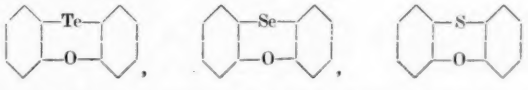
Part XXV.—A Quantised Phenomenon: The Halochromic Colours of the Doubly-linked Diphenylene Compounds.

By James Moir.

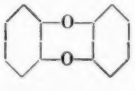
This investigation commenced four years ago in a study of organic fluorescence: a number of preliminary observations were published as Part XIX of this series (these Trans., XII (II), 1925, p. 45).

The observations were of a surprisingly confused nature, and no relation between chemical constitution and wave-lengths could be discovered,* although such relationship is usually easy to find in other families of coloured substances. Thus anthracene, the highest band of which in ordinary solvents lies at about λ 378, was found to have, in concentrated H_2SO_4 solution, an absorption in the extreme red (λ 702) in addition to bands in more normal places.

The recent work of Drew (J. Chem. Soc., London, 1928, p. 511, and four earlier papers) on



and the bright colours which they give in sulphuric-acid solution re-attracted me to the subject. It became important to find out about



which I had stated (Part XIX, p. 48) not to exist. The truth turns out to be that this substance was discovered in 1906, but has been omitted from all chemical indexes save one, and I have to thank Professor Henry Stephen not only for "running it to earth" but also for giving me material for making it. This substance also, contrary to all expectation from its constitution, gives a blue H_2SO_4 solution, although colourless in all other

* This is not due to sulphonation in some cases and not in others. The temperatures were too low and the observations too quick for this.

solvents (Ullmann and Stein, Berichte, 1906, p, 622, but more easily obtainable from orthochlorophenol).

The author has made, and examined in H_2SO_4 solution, practically the whole of the possible compounds in which two benzene rings are connected (in ortho positions) by two identical or different elements or their derivative oxidised groups. The omissions are mainly compounds of tellurium, and it can safely be expected that when discovered they will not differ materially in regard to the property under investigation from those of selenium.

The following table gives the observations :—

TABLE OF HALOCHROMIC (H_2SO_4) COLOURS.

Name.	9 : 10 grouping.	$\lambda\lambda$ in $\mu\mu$.	$\nu\nu$ ($\lambda\nu = 10^7$).
Dihydroanthracene	CH_2, CH_2	352, 400	28400, 25000
Anthracene	CH—CH	421, 330, 702	23750, 30300, 14250
Anthranol	CH—C(OH)	487	20530
Anthraquinol	C(OH)—C(OH)	about 450	22220
Anthraquinone	CO, CO	403	24810
Dihydrophenazine	NH, NH	417, 398, 434	24000, 25120, 23000
Phenazine	N—N	503, 552, 473	19900, 18100, 21100
Phenazonium	N—NO	same ; uncertain which is which.	
Phenoxine (diphenylene dioxide)	O, O	683, 655, 628	14650, 15280, 15930
Thianthrene	S, S	548, 520	18250, 19220
Thianthrene monoxide	S, SO	same ; uncertain which is which.	
Thianthrene dioxide	SO, SO	730, 497	13700, 20110
Thianthrene trioxide	SO, SO_2	about 422	23700
Thianthrene tetroxide	SO_2, SO_2	about 342	29300
Selenanthrene	Se, Se	486, 360, about 750	20590, 27780, 13330
Selenanthrene oxide	Se, SeO		
Dihydroacridine	CH_2, NH	430, 408, 340	23250, 24500, 29400
Acridine	CH—N	355	28160
Acridone	CO, NH	336	29770
Xanthene	CH_2, O	360, 425	27780, 23520
Xanthhydrol	CH(OH), O	450	22220
Xanthone	CO, O	340, 405	29400, 24700
Thioxanthene	CH_2, S	about 380	26300
Thioxanthhydrol	CH(OH), S	445	22480
Thioxanthone	CO, S	486, 458, 351, 322	20580, 21810, 28480, 31050
Selenoxanthone	CO, Se	350, 320	28580, 31260

Phenoxazine	NH, O	539, 417, 502	18560, 24000, 19940
Phenoxazonium	NOH, O	463	21600
Phenthiazine	NH, S	518, 496, 478	19300, 20180, 20910
Phenthiazonium	NOH, S	730, 670, 460, 446	13700, 14930, 21800, 22410
Phenselenazine	NH, Se	522, 474	19150, 21100
Phenselenazonium	NOH, Se	740, 435, 579	13520, 23000, 17270
Phenthioxine	O, S	586	17070
Phenthioxine oxide	O, SO	491, about 760	20380, 13150
Phenthioxine dioxide	O, SO_2	370	27030
Phenoxselenine	O, Se	583, 472	17150, 21180
Phenoxselenine oxide	O, SeO	same; uncertain which is which.	
Phenoxtellurine	O, Te	512, 480	19530, 20820
Phenoxtellurine oxide	O, TeO	392	25510
Phenoxtellurine quinhydrone	†	750, 570, 440	13330, 17550, 22720
Phenoxtellurine dioxide	O, TeO_2	about 350	28600

The author was compelled to do this immense amount of preparative work, because a solution of the problem would not come out. Light was first thrown on the puzzle when it was noted that one can make the wave-numbers ($\nu\nu$) of the strongest line of most of the substances identical by division sums. Thus the wave-number of phenoxine divided by 6 equals those of phenthioxine and phenoxselenine divided by 7, and also equals that of phenoxtellurine divided by 8 :—

$$\frac{14650}{6}=2442,\quad \frac{17070}{7}=2439,\quad \frac{17150}{7}=2450,\quad \frac{19530}{8}=2441.$$

So for thianthrene the divisor is $7\frac{1}{2}$ and for selenanthrene $5\frac{1}{2}$ and $8\frac{1}{2}$. The similarity of effect of sulphur and selenium appears also in their nitrogen compounds.

Hence, to begin with, the colours have very little to do with the actual linking elements, but depend on the fact that all the molecules are of the same shape and are very nearly all of the same size. The actual wide differences in the positions of the absorptions are really due to change in the value of the harmonic number (or of some similar *integral* constant in the wave-mechanics theory (which I confess I cannot understand)).

Secondly, it was then found that although the foregoing discovery applies only to the hexad elements, it could be made applicable, by a further division sum, to all the rest of the observations. If the above constant of

† Drew's purple compound (J. Chem. Soc., London, 1926, p. 3055, and 1928, p. 508).

value 2440 (waves per centimetre) be divided by 4 and then allowed to vary very slightly according to the chemical constitution of the substances (or rather of the two 9 : 10 links in their unoxidised state) between the limits of 594 for the lowest element and 612 for the highest, *the whole of the observations* can be represented in the form of this "constant" multiplied by *a number of integers.*

The experimental error being of the order of 0·1 to 0·2 per cent., and the error due to changing the integer by unity being 3 per cent., this cannot be due to coincidence.

The results follow :—

Anthracene series : ν calc.$=594\times(\mathit{24}, \mathit{40}, \mathit{50}, \mathit{48}, 42, \mathit{42}, 35, 37)$.
$=14260, 23760, 29700, 28510, 24950$ (*bis*), $20790, 21980$.
calc. $\lambda\lambda=701, 421, 337$ (anthracene) : $350\frac{1}{2}$, 401 (dihydroanthracene) : 401 (anthraquinone) : 482 (anthranol) : 455 (anthraquinol).

Acridine series : ν calc.$=597\times(\mathit{39}, 41, 49, \mathit{47}, \mathit{50})$.
$=23280, 24480, 29250, 28060, 29850$.
calc. $\lambda\lambda=430, 409, 342$ (dihydroacridine) : 356 (acridine) : 335 (acridone).

Xanthene series : ν calc.$=602\frac{1}{2}\times(\mathit{41}, \mathit{49}, \mathit{46}, 39, \mathit{37})$.
$=24700, 29520, 27710, 23500, 22290$.
calc. $\lambda\lambda=405, 339$ (xanthone) : 361, 426 (xanthene): 449 (xanthhydrol).

Thioxanthene series : ν calc.$=606\times(34, 36, \mathit{47}, 51, \mathit{43}, \mathit{37})$.
$=20600, 21820, 28480, 30910, 26060, 22420$.
calc. $\lambda\lambda=486, 458, 351, 323$ (thioxanthone) : 384 (thioxanthene) : 446 (thioxanthydrol).

Selenoxanthene series : ν calc.$=609\times(\mathit{47}, 51)$.
$=28620, 31060$ (selenoxanthone).
calc. $\lambda\lambda=349, 322$.

Phenazine series : ν calc.$=603\times(\mathit{40}, 42, 38, 33, 30, 35)$.
$=24120, 25330, 22910, 19900, 18090, 21100$.
calc. $\lambda\lambda=415, 395, 436$ (dihydrophenazine) : 502, 553 (phenazine) : 474 (phenazonium sulphate).

Phenoxazine series : ν calc.$=600\times(\mathit{40}, 31, 33, 36)$.
$=24000, 18600, 19800, 21600$.
calc. $\lambda\lambda=417, 538, 505$ (phenoxazine) : 463 (phenoxazonium sulphate).

Thianthrene series: ν calc.=608×(*30*, 32, *22*, 33, 39, 48).
=18240, 19460, 13380, 20060, 23710, 29180.
calc. $\lambda\lambda$=548, 514 (thianthrene): 747, 498 (diphenylene disulphoxide): 421 (diphenylene sulphoxide-sulphone): 343 (diphenylene disulphone).

Phenoxine (phenoxozone): ν calc.=610×(*24*, 25, 26).
=14640, 15250, 15860.
calc. $\lambda\lambda$=683, 656, 630 (phenoxine, only one substance).

Phenthioxine (phenoxthionine): ν calc.=609½×(*28*, 22, 33, 44).
=17070, 13410, 20110, 26820.
calc. $\lambda\lambda$=586 (phenthioxine): 745, 497 (diphenylene-oxide sulphoxide): 373 (phenthioxine dioxide).

Phenthiazine (thiodiphenylamine) series: ν calc.=603×(*32*, 34, 35, 23, 25, 36, 37).
=19300, 20500, 21100, 13870, 15070, 21710, 22310.
calc. $\lambda\lambda$=518, 488, 474 (phenthiazine): 721, 664, 461, 448 (phenthiazonium sulphate and phenthiazine dioxide).

Phenselenazine series: ν calc.=600×(*32*, 35, 22, 29, 38).
=19200, 21000, 13200, 17400, 22800.
calc. $\lambda\lambda$=521, 476 (phenselenazine): 757, 574, 439 (phenselenazonium sulphate).

Phenoxselenine series: ν calc.=612×(*28*, 35).
=17140, 21420.
calc. $\lambda\lambda$=583 (phenoxselenine): 467 (diphenylene-oxide selenoxide).

Phenoxtellurine series: ν calc.=610×(*32*, 34, 42, 22, 29, 37, 47).
=19520, 20740, 25620, 13320, 17690, 22570, 28670.
calc. $\lambda\lambda$=512, 482 (phenoxtellurine): 390 (diphenylene-oxide telluroxide): 750, 566, 444 (quinhydrone): 349 (phenoxtellurone).

Selenanthrene series: ν calc.=605×(22, 34, 46).
=13310, 20570, 27830.
calc. $\lambda\lambda$=751, 486, 359 (selenanthrene and its oxide).

Again, we find amongst the harmonic factors (the integers in brackets), in spite of their "higgledy-piggledy" nature, some marked regularities.

Thus replacement of CH_2 by O depresses the relative integer by 3, and replacement of CH_2 by NH alters the factor by $+1$ and -1, reminding one of the changes of J in the quantum theory. Also the values: Se Se=34, O Te=32, S S=30, O Se=28, O S=28, and O O=24 are very regular and suggest something depending on the 30 valency-electrons of the benzene ring; * but there appears no explanation of the series 35, 37, 39, 41, 47 in the CC, CO, and CS family.

The whole phenomenon seems to depend more on the benzene rings than on the linkages, the latter merely altering the constant (of value of about 600) by 1 or 2 per cent. In default of a mathematical hypothesis nothing further can at present be done with the data, but I invite the attention of the experts to this field, where they might obtain results.

Attempt to apply Quantum or Factorial Principles to Substances containing Auxochromes.

It became of interest to see whether any regularities could be found among the triphenylcarbinol data given in the previous part of this series. In the first place, it is obvious that they do not fit into any *single* system, although (like the substances just discussed) they belong to a single chemical family; in quite a number of cases a single substance has two bands so close together (*e.g.* $\lambda\lambda$ 558 and 564) that they could not result from successive integral harmonics.

Nevertheless some quite remarkable results can be calculated. Thus:

$\nu\nu$ for	dihydroxybenzhydrol	agree with	$285 \times (65, 72, 78)$.
,,	benzaurine	,,	$282\frac{1}{4} \times (64, 72, 78)$.
,,	malachite-green	,,	$270\frac{1}{4} \times (60, 84)$.
,,	aminomalachite-green	,,	$284\frac{1}{2} \times (56, 60, 76, 84)$.
,,	diaminobenzhydrol	,,	$480 \times (36, 38, 42)$.
,,	fuchsine	,,	$513 \times (34, 36, 54)$.
,,	dimethyldiaminofuchsone	,,	$471 \times (34, 36, 40, 43, 46, 50)$.

It must, I think, be admitted that harmonics so high as the 65th one are extremely unlikely as simple harmonics. The real side of it is the ratio 6 : 5 between two of the bands, and the ratio 13 : 12 between one of these and the third: as the bands are due to *differences* of energy, they are expressible as *differences of two vulgar-fractions*, which may of course lead to very peculiar arithmetical results.

* The great majority of the *molecules* under discussion have a total of 68 valency-electrons.

NOTE ON THE LAGRANGIAN OF A SPECIAL UNIT DETERMINANT.

By Sir Thomas Muir, F.R.S.

1. The unit determinant in question when of the n^{th} order has for the elements of its first column the coefficients of the expansion of $(a+b)^{n-1}$ taken all negative when the power-index is odd and all positive when it is even, the other columns being similarly obtained from $(a+b)^{n-2}$, $(a+b)^{n-3}$, ... supplemented by zeros; thus when n is 3 and when n is 4 the examples are

$$\begin{vmatrix} -1 & 1 & -1 & 1 \\ -3 & 2 & -1 & . \\ -3 & 1 & . & . \\ -1 & . & . & . \end{vmatrix}, \quad \begin{vmatrix} 1 & -1 & 1 & -1 & 1 \\ 4 & -3 & 2 & -1 & . \\ 6 & -3 & 1 & . & . \\ 4 & -1 & . & . & . \\ 1 & . & . & . & . \end{vmatrix}$$

the corresponding Lagrangians being

$$\begin{vmatrix} -1-\lambda & 1 & -1 & 1 \\ -3 & 2-\lambda & -1 & . \\ -3 & 1 & -\lambda & . \\ -1 & . & . & -\lambda \end{vmatrix}, \quad \begin{vmatrix} 1-\lambda & -1 & 1 & -1 & 1 \\ 4 & -3-\lambda & 2 & -1 & . \\ 6 & -3 & 1-\lambda & . & . \\ 4 & -1 & . & -\lambda & . \\ 1 & . & . & . & -\lambda \end{vmatrix}$$

2. If we denote the Lagrangian of the n^{th} order by L_n, those just written are L_4, L_5, and we can readily see that

$$L_1 = 1-\lambda,$$

$$L_2 = \begin{vmatrix} -1-\lambda & 1 \\ -1 & -\lambda \end{vmatrix} = 1+\lambda+\lambda^2,$$

$$L_3 = \begin{vmatrix} 1-\lambda & -1 & 1 \\ 2 & -1-\lambda & . \\ 1 & . & -\lambda \end{vmatrix} = 1-\lambda^3,$$

so that thus far the latent roots of our unit determinant are the cube roots of 1.

3. *The Lagrangian* L_n *is not altered in substance by annexing* $-\lambda$ *to each of the elements of its main diagonal except the last and to each element of the adjacent minor diagonals.* For example, besides the standard form given above for L_4 we have

$$L_4 = \begin{vmatrix} -1-2\lambda & 1-\lambda & 1 & -1 \\ -3-\lambda & 2-2\lambda & 1-\lambda & . \\ -3 & 1-\lambda & -2\lambda & -\lambda \\ -1 & . & -\lambda & -\lambda \end{vmatrix}.$$

This is perhaps most concisely proved by showing that the operation

$$\text{col}_r + \text{col}_{r+1} \qquad (r=1, 2, \ldots .)$$

followed by the operation

$$\text{row}_r + \text{row}_{r+1} \qquad (r=1, 2, \ldots .)$$

leads directly from the one form to the other. Thus, taking the first form of L_5 and increasing each of its columns in order by the next column, we obtain

$$\begin{vmatrix} -\lambda & . & . & . & 1 \\ 1-\lambda & -1-\lambda & 1 & -1 & . \\ 3 & -2-\lambda & 1-\lambda & . & . \\ 3 & -1 & -\lambda & -\lambda & . \\ 1 & . & . & -\lambda & -\lambda \end{vmatrix},$$

and then by operating on the rows of this in the same manner there results

$$\begin{vmatrix} 1-2\lambda & -1-\lambda & 1 & -1 & 1 \\ 4-\lambda & -3-2\lambda & 2-\lambda & -1 & . \\ 6 & -3-\lambda & 1-2\lambda & -\lambda & . \\ 4 & -1 & -\lambda & -2\lambda & -\lambda \\ 1 & . & . & -\lambda & -\lambda \end{vmatrix},$$

as desired.

4. *Any Lagrangian* L_n *contains* L_3 *as a factor, the cofactor being* L_{n-3}, n *of course being greater than* 2.

This is made clear by performing on L_n the operation

$$\text{col}_r + \text{col}_{r+1} \qquad (r=1, 2, \ldots .)$$

and then on the second row of the result the operation

$$\text{row}_2 - \text{row}_3 + \text{row}_4 - \ldots ,$$

for L_n is thus so altered in appearance that the two factors in question are manifest on the face of it.

Taking the case where n is 7 as an illustration and acting on its columns as stated, we obtain

$$\begin{vmatrix} 1-\lambda & -1 & 1 & -1 & 1 & -1 & 1 \\ 6 & -5-\lambda & 4 & -3 & 2 & -1 & . \\ 15 & -10 & 6-\lambda & -3 & 1 & . & . \\ 20 & -10 & 4 & -1-\lambda & . & . & . \\ 15 & -5 & 1 & . & -\lambda & . & . \\ 6 & -1 & . & . & . & -\lambda & . \\ 1 & . & . & . & . & . & -\lambda \end{vmatrix} = \begin{vmatrix} -\lambda & . & . & . & . & . & 1 \\ 1-\lambda & -1-\lambda & 1 & -1 & 1 & -1 & . \\ 5 & -4-\lambda & 3-\lambda & -2 & 1 & . & . \\ 10 & -6 & 3-\lambda & -1-\lambda & . & . & . \\ 10 & -4 & 1 & -\lambda & -\lambda & . & . \\ 5 & -1 & . & . & -\lambda & -\lambda & . \\ 1 & . & . & . & . & -\lambda & -\lambda \end{vmatrix},$$

and following this up with the transformation of the new second row we have

$$\begin{vmatrix} -\lambda & . & . & . & . & . & 1 \\ -\lambda & . & . & . & . & -1 & \lambda \\ 5 & -4-\lambda & 3-\lambda & -2 & 1 & . & . \\ 10 & -6 & 3-\lambda & -1-\lambda & . & . & . \\ 10 & -4 & 1 & -\lambda & -\lambda & . & . \\ 5 & -1 & . & . & -\lambda & -\lambda & . \\ 1 & . & . & . & . & -\lambda & -\lambda \end{vmatrix},$$

which by Laplace's expansion-theorem

$$= \begin{vmatrix} -4-\lambda & 3-\lambda & -2 & 1 \\ -6 & 3-\lambda & -1-\lambda & . \\ -4 & 1 & -\lambda & -\lambda \\ -1 & . & . & -\lambda \end{vmatrix} \cdot \begin{vmatrix} -\lambda & . & 1 \\ -\lambda & -1 & \lambda \\ 1 & -\lambda & -\lambda \end{vmatrix}$$

$$= L_4 \cdot L_3.$$

It will be observed that L_4 makes its appearance in a form intermediate between the plain original and the more elaborate form of § 3, being, however, separated from the latter merely by the operation $\mathrm{col}_r + \mathrm{col}_{r+1}$. A note must also be made in regard to the form of L_3, which not only is not the original but is inconstant, being as here when n is odd, and being

$$\begin{vmatrix} -\lambda & . & 1 \\ -\lambda & -1 & -\lambda \\ -1 & -\lambda & -\lambda \end{vmatrix}$$

when n is even.

5. By repeated use of the result just reached we have

$$L_n = L_3 L_{n-3} = L_3 \cdot (L_3 L_{n-6}) = \ldots .$$
$$= (L_3)^k L_{n-3k},$$

where $3k$ is the highest multiple of 3 that is less than n. This is the same as the triple equality

$$L_{3k} = L_3{}^k, \quad L_{3k+1} = L_3{}^k L_1, \quad L_{3k+2} = L_3{}^k L_2 ;$$

and as we know that L_1L_2 may be substituted for L_3 a third form is clearly available.

6. The individual instances here occurring of the equality

$$L_m \cdot L_n = L_{m+n}$$

suggest inquiry as to its generality. It is clear, in the first place, that it must hold when m or n is a multiple of 3; for we have just shown that

$$L_{3k+n} = L_{3k} \cdot L_{(3k+n)-3k} \quad i.e.\ L_{3k}L_n.$$

When neither is a multiple of 3, it still holds when their sum is such a multiple, or, what is the same thing, when one of them is of the form $3p+1$ and the other of the form $3q+2$; for then

$$\begin{aligned} L_{3p+1}L_{3q+2} &= L_3{}^pL_1 \cdot L_3{}^qL_2 \\ &= L_3{}^{p+q+1} \\ &= L_{3p+3q+3}. \end{aligned}$$

If, on the other hand, m and n be of the same form, the outcome is different; for example

$$\begin{aligned} L_{3p+1}L_{3q+1} &= L_{3p}L_1 \cdot L_{3q}L_1 \\ &= L_{3p+3q} \cdot L_1{}^2, \end{aligned}$$

and $L_1{}^2$ is not equal to L_2, as would otherwise be necessary.

7. The result of § 5 above is given by Professor H. W. Turnbull in a note just published by the Edinburgh Mathematical Society (see *Notes*,* No. 24, pp. 14–16).

Rondebosch, S.A.,
14*th February* 1929.

* It is gratifying to see these *Mathematical Notes* vigorously revived after an interval of over three years. The new editor is Dr. A. C. Aitken.

NOTES ON TWO LARVAE OF SOUTH AFRICAN DIPTERA BELONGING TO THE FAMILIES *LEPTIDAE* AND *ASILIDAE*.

By Dr. E. O. Engel, Munich.

(Communicated by Dr. E. L. Gill.)

(With twenty Text-figures.)

This paper contains morphological and biological notes on two dipterous larvae which I received through Dr. Brauns, Willowmore, to whom I wish to express herewith my sincerest thanks.

I obtained living specimens of the interesting Leptid larva *Lampromyia sericea* Westwood, famous for constructing pitfalls in the sand in order to catch ants and other insects for food. I was thus enabled to study the biology of this fly, not under quite natural conditions, it is true, but fairly thoroughly.

Further, I received four larvae and one pupa of the Asilid *Hyperechia nigripennis* Wied., which proved to be remarkable for the reduction of the larval mouth-parts.

I. Larva of Lampromyia sericea Westwd.

This fly belongs to the family *Leptidae* (*Rhagionidae*), and within that family to the well-defined group of *Vermileoninae*.

The larvae of this great and widespread family are remarkable for their various forms and habits. The majority are predaceous and some are scavengers.

If we compare, for instance, the mouth-parts of *Leptis* (*Rhagio*), *Atherix*, and *Lampromyia* we can recognise the same plan of structure in spite of the totally different forms and habits of the larvae. Common to all of them is the head-capsule closed only dorsally, and the long maxillae which show many sensory buds. All these genera are present in Africa. The genus *Vermileo* occurs in Southern Europe (*degeeri* Macqu.) and North America, California (*comstocki* Wheeler); the genus *Lampromyia* in Spain, Canary Isles, and Africa.

For further information about the larvae and pupae of *Leptidae*, see Greene (Ch. T.), Proc. U.S. Nat. Mus., vol. lxx, Art. 2, No. 2651, 1926, where some American genera of the family are represented.

The larvae of *Vermileoninae* were already known to Degeer (1752), and later were treated by Reaumur (1753) and Westwood (1840). All these authors studied the South European *Vermileo degeeri* Macqu., about which Westwood writes: "The larva has the singular habit of forming small conical holes in the sand, like the ant-lion, for the purpose of entrapping small insects, round which it entwines itself, and destroys and sucks them" (Westwood: Introduction, ii, 552, 1840). The same author cites de Romand (Ann. Soc. Ent. de Fr., ii, 1833), who observed the larva of *Vermileo* during three years, and gives many details about the habits, which fully agree with my observations of *Lampromyia sericea* Westwd.

Brauer (F.) (Zweiflügler d. Kaiserl. Museums zu Wien, III, vol. xlvii, Denkschr. d. K. Akad. d. W., 1883) figures the larva and the mouth-parts of *V. degeeri* (figs. 84–88). The mouth-parts are not well represented. A better figure of the American *V. comstocki* is drawn by Greene (*loc. cit.*, pl. i, fig. 6); unfortunately it is too small for recognition of details.

Brauer's fig. 84 shows clearly the ventral wart (Haltfuss) of the 5th segment. He counts for *Leptidae* in general 13 segments, which are distributed by the ganglia to the following divisions of the body: 2 to the head; 3 (+1) to the thorax; 2 anal segments are fused into one. But the same author says (p. 25), "body with 11 to 12 segments."

An interesting account of his observations on *Lampromyia pallida* Macqu. is given by Bequaert (J.) (III. "The predaceous enemies of Ants," Bull. Amer. Mus. of Nat. Hist., vol. xlv, 1922, p. 278): "During my stay at Algiers in June 1910, I had the good fortune to observe rather closely the larvae of a species of this genus, probably *L. pallida*. They were found in numbers on the outskirts of Mustapha Superieur, along the highway to Blidah, in the suburb of Colonne Voirol. Wherever the soft sandstones of the road-banks happened to be excavated or weathered into miniature caves, one was sure to find the dry, powdery dust beneath the shelter of the overhanging rock fairly dotted with the funnelled pits of *Lampromyia*. At that season adult flies were frequently seen resting on the rocky ceilings of the excavations. I found that the most common victims of these larvae were workers of the little *Tapinoma erraticum* (Latreille)."

I may add that my friend Mr. Lichtwardt reared this species in Berlin from larvae which he had received from Barcelona, Spain. I studied pupae and cast larval skins from his collection.

Bequaert mentions (*loc. cit.*, p. 277, Note 2) that the earliest reference to the habits of *Vermileo* is by an anonymous writer in Histoire Ac. Sci. Paris (1706), 1731, pp. 7–8, where it is called *Formica-vulpes*. The same author cites (*loc. cit.*, p. 278, Note 2) Marchal, P., 1897, "Notes d'entomologie biologiques sur une excursion en Algérie et en Tunisie," *Lampromyia*

miki nov. sp. (=*pallida* Macqu.); Cecidies (Mém. Soc. Zool. France, x, pp. 5–25, pl. i).

Description of Larva.

Total length, 11–18 mm.; breadth of anal segments, 2·75–3 mm.; of segments of thorax, 1·25–1·5 mm. Material collected by Dr. Brauns, Stellen-

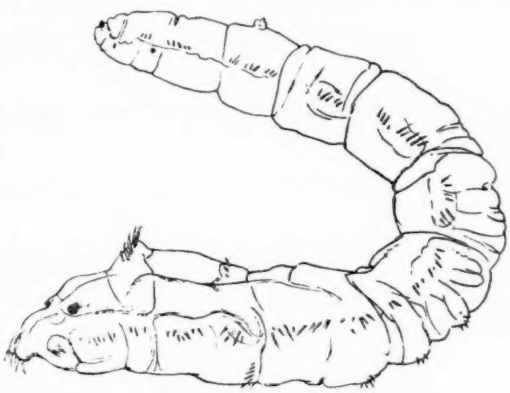


Fig. 1.—Larva of *Lampromyia sericea* Westw.

bosch, Cape Colony. The colour of the living larva is reddish-ochraceous, which becomes darker and more dirty anally, on account of the blackish content of the intestines. The whole body is covered by adhering particles of sand, fixed by innumerable fine hairs on the skin. These hairs are of varying shape and length, but longest on the lateral line which runs round the whole body.

Fig. 2.—Haftfuss, larva of *Lampromyia sericea* Westw.

Twelve segments may be counted, the boundaries of which are difficult to point out, and which become broader anally, so that the tenth or eleventh is broadest. The fifth segment bears a ventral papilla (Haftfuss of Brauer). On this median papilla the larva fixes the head for the purpose of throwing sand or other objects out of the pitfall, as will be described later on. Many sensitive buds surround the papilla, and a blind-sac of the intestine is given off into it.

The papilla itself is composed of three processes, the median one having the form of an anchor and the lateral ones being of simple cylindrical form. The mouth-parts seize the median process from behind, so that the four preceding segments form the upper part of a roman S. Then the larva

stretches the body a little, the mouth-parts glide off from their hold, and the head acts like the strained end of an elastic steel which had been bowed together by its two ends, for the rest of the larval body remains firmly anchored in the sand of the pitfall. The movement is too quick for one to see more than the effect of the mechanism. As the anal end remains fixed to one point in the depth of the homogenous fine sand, it is easy to understand how the conical form of the pitfall is constructed by the larva.

The anterior dorsal margin of the 11th segment bears a scanty row of short spines; the same part of the 12th segment a row of strong, forwardly-bent hooks, and in front of them a row of short spines. By these hooks and spines the larva is anchored in the sand of the centre of the pitfall. The anal end is divided into four lobes, which are laterally surrounded by long and dense hairs, directed ventrally.

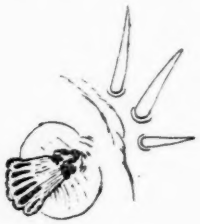


FIG. 3.—Larva of *Lampromyia*. Prothoracic spiracle.

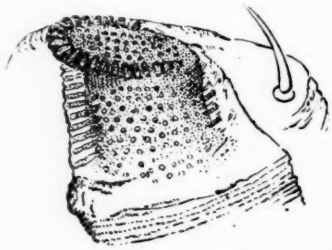


FIG. 4.—Anal spiracle, No. 1, larva of *Lampromyia sericea* Westw.

The third and twelfth segments have a pair of spiracles each; the larva is amphipneustic. The anterior (prothoracic) spiracle on the third segment is very small, and necessarily so, for the anterior part of larva is always exposed to the open air. It is situated above the fringe of long hairs which laterally runs round the whole body, and a little behind the end of the head-capsule. The exterior part, or stigmatic plate, has the shape of a half-opened fan, and bears six to seven stigmatic openings. The stigmatic chamber (Filzkammer) is rather long in comparison with the plate itself. The stigmatic scar lies at the base of the fan.

The anal spiracle on the 11th segment is of quite different construction from the anterior one; it belongs to the multiphorous type (of Schiödte and Melin). There are many stigmatic openings on the periphery of the stigmatic plate. The whole spiracle can be covered by a fold of the skin. Somewhat distally and laterally to it is a long sensory hair. The stigmatic chamber is scarcely longer than the greatest diameter of the stigmatic plate. The stigmatic scar (central-piece, Melin) lies excentrically and anally.

Besides the stigmatic openings, arranged peripherally, the whole plate is covered by many small pores, from which tubes lead into the stigmatic chamber. From the latter other tubes lead directly into the body of the larva.

I clearly saw the air pass by pressure through the stigmatic openings, but never through the fine pores which cover the surface of the plate, nor through the stigmatic scar or central-piece.

Head of Larva.

The head-capsule is dorsally closed and ventrally open. To the arched ceiling are attached two prolongations (Zopfgräten of Brauer) which flank

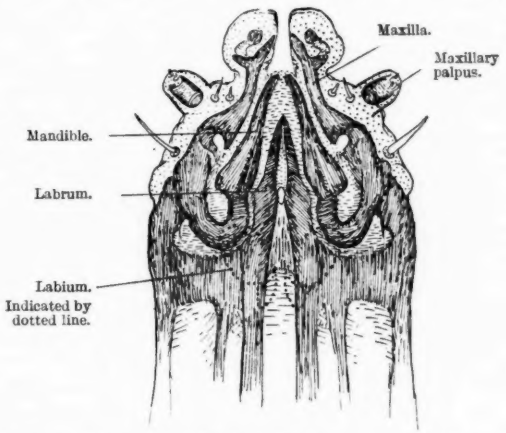


FIG. 5.—Larva of *Lampromyia sericea* Westw. Mouth-parts, dorsal view.

the oesophagus, and bear on the lower edge of their broad anterior part the two parts of the labium. This closes from below the aperture of the mouth, which is closed from above by the broad fleshy maxillae. The maxilla bears on its membranaceous part a maxillary palpus and on its tip a sensory bud, while its strongly chitinized interior support is jointed to a half ring, on the dorsal end of which the mandibular hook is articulated. This half ring is clearly to be seen on each side of the dorsal end of the head-capsule, to which it is likewise articulated. The two sclerites of the labrum are pointed, its distal part is broad and membranaceous and does not reach the end of the mandibular hooks. These are very pointed and their surface shows a peculiar structure (figs. 5, 6, and 6A). The arrangement of mouth-parts is the same in the larvae of *Vermileo*, and very similar in *Leptis* (*Rhagio*) and

Atherix. It may be compared with the structure of the cephalopharyngeal

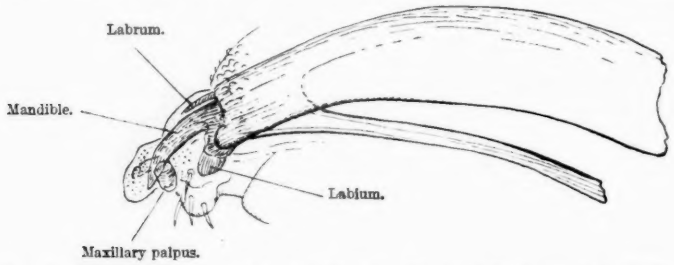


FIG. 6.—Larva of *Lampromyia sericea* Westw. Head and head-capsule in profile.

FIG. 6A.—Larva of *Lampromyia sericea* Westw. Mandibular hooks and labrum.

skeleton of *Diptera Cyclorrhapha*. The topmost pair of dorsal prolongations (compare fig. 3, page 21, in Efflatoun, on "The Morphology of some Egyptian Trypaneid Larvae," Bull. Soc. Roy. Entom. d'Egypte, 1927) is fused to the dorsal arched ceiling in *Lampromyia*; the next dorsal pair is present, while the ventral two pairs are atrophied. The half ring to which the mandibular hooks and maxillae are articulated may be derived from the sub-hypostomal sclerite, and the hypostomal sclerite forms the chitinized support of the labrum.

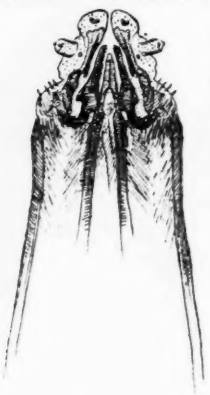


FIG. 7.—Larva of *Lampromyia pallida* Macq. Head-capsule, dorsal view.

The mouth-parts of *Lampromyia pallida* Macqu. from Spain differ only in the chitinized support of the maxillae, which is bilobed, not forked as in *L. sericea* (fig. 7).

Habits of the Larva.

On 22nd December 1926—here a cold winter day with snow 25 cm. deep covering all—I received a small box through my friend Dr. Brauns of Willowmore, and this box contained reddish sand (1½ feet African sand, as a small label stated) and 6–8 motionless larvae of a *Lampromyia* lay imbedded herein.

When brought into a warm room they began to move, and by the morning of the following day some of them had already constructed their peculiar pitfalls. I now put the box into a larger glazed cage, the bottom of which was covered with a layer of sand, and gently removed the sides and bottom of the transport-box. On the evening of the same day one larva had built a new pitfall in the surrounding white calcarious sand.

The cage was then placed on the radiator of a warm-water heating apparatus, where the constant temperature of about 20° C. was reduced by the glass cage to what I thought might be agreeable to the little animals. But now arose a far more serious question, namely, that of the food for my Africans. In the cellar of my house I found only wintering *Culex*, and this was almost all I could offer them. Two to three meagre *Culex* per day for each larva, and they rarely took more. For the purpose I cut off the wings of the living *Culex*, for the food must be alive, and put them into the pitfall. Seeing that the intervals between these pitfalls, each of which had a diameter of almost 4 cm., were not very large, it often happened that a struggling *Culex* removed sand-grains from the wall of one pitfall which fell into the centre of another, and this was promptly answered by eruptions of sand, falling again on the head of the next larva, so that in a short time a regular bombardment spread over all the eight pitfalls.

These eruptions are produced in the following manner. The larva, which is firmly anchored by its thick-set anal-end in the sand below the centre of the pitfall, so that only the first six to seven segments are visible, bows the head and fixes the mouth-parts on the papilla, lying ventrally on the fifth segment. It then lets loose the wart, and, throwing the head backwards with a sudden jerk, hurls the objects from out of the pitfall. The sucked-out bodies of the victims, and even the cast skins of the larva itself, are removed in this way. The larva grasps its prey in a manner which reminds one of a python. The head and the first three to four segments of the larval body twist round the victim, and the mouth-parts begin to seek a place where the pharynx can be introduced in order to suck the blood-liquor of the *Culex*.

Generally only a leg of the prey is seized, and this is always treated in the same manner. The maxillae finger the surface of the seized part till a place is found where the act of sucking can begin. When the prey is weakened by the loss of blood-liquor another place of attack is often sought—for instance, the intersegmental parts between the sternites of the abdomen, or the occiput. After ten to twenty minutes' sucking the victim is generally pulled totally into the sand, and thus hidden from any further observation.

Some Observations.

Small spiders are not attacked at all; they are either frightened by charges of sand, or the larva retreats instantaneously into the sand. A

Staphylinid beetle was attacked, but got free again; then it was seized by another larva and drawn into the sand. Only once could I get ants for food, but, unfortunately, could not see how they were seized by the larva. De Romand (*loc. cit.*), speaking of *L. pallida*, tells us that ants were always seized between head and thorax in order to avoid a bite. But how is it with a sting? I think ants will also be drawn into the sand, where the larva is less exposed to the danger of being stung.

The best observation I made was with a big *Pollenia* (Dipteron). The right hind-leg of the fly was seized and the mouth-parts of the larva fixed on the upper part of the tibia. After twenty minutes' sucking by the larva the fly sank to the left side and gave no more signs of life if touched by a needle. Five minutes later the larva let loose the leg of the fly and anchored the mouth-parts into the occiput. After eight minutes' sucking the whole fly was drawn into the sand. Three hours later I found the victim ejected from the pitfall. The right hind-leg proved shrivelled, as in a freshly moulted insect, while the other legs were in perfect condition. I put the fly into alcohol for further research, which had no result. It was impossible to see any lesion, even under the highest magnification possible. The pointed end of the pharynx must enter into one of the fine pores of the fly's chitin, and perhaps an extra-intestinal digestion takes place, accelerating the death of the victim. The shrivelling of the seized leg strongly supports this view.

Change of light and shadow makes not the least impression to the larva. I often gave food in the evening under the light of a strong electric lamp, and many times the focus of my lens hit a larva without producing any effect at all; but the least shock, even a cough, made all the larvae disappear. When the larva casts the skin it ceases to take food; the pitfall becomes ruinous, and looses the perfectly smooth interior encircled by a wall of the larger sand particles; or a flat plane of fine sand covers the centre of the hole and reminds one of a burnt-out volcano. The skin of the larva bursts at the neck and is then thrown out in the manner described above, and the pitfall is restored again. These cast skins offer the best material for the study of the mouth-parts and the spiracles. I found no change in the mouth-parts of this orthorhaphous larva, such as generally takes place in the larvae of *Diptera Cyclorrhapha*, but I saw only half- or full-grown larvae, in which the changes of structure in those parts are scarcely perceptible.

After three months, in the middle of May, just at a time when our palaearctic insect life begins to awaken, all my larvae refused to take food and the pitfalls began to fall in. This period lasted till the 5th October, when two new pitfalls, but of smaller dimensions than usual, were constructed. Those of the first season measured from 3 to 3·5 cm. in diameter, while they now reached scarcely 2 cm. Four larvae were present, but

only two took food, and even this at intervals of from two to four days. On the 14th November no more larvae were to be seen. On 21st October a fine male fly emerged from a pupa. All the others proved to be females, the last of these emerging on 1st March.

Description of Pupa.

Head and thorax of pupa are brownish, abdomen yellowish in colour. Total length varying from 11 to 18 mm. Width of thorax, 2·5 to 3 mm.; and that of anal segments, 1·25 to 1·5 mm. (fig. 8).

The facialia of the head bear at each side a crest of flat spines—three larger ones on the lower and two smaller ones on the upper part. The sheath of the proboscis reaches almost to the end of that of the fore-legs. The thorax is in profile a little hump-backed, and at each side bears three flat, spine-like processes—one above the prothoracic spiracle and two others at base of wings (fig. 9).

The abdomen consists of seven segments, the last of

FIG. 8.—Pupa, *Lampromyia sericea* Westw.

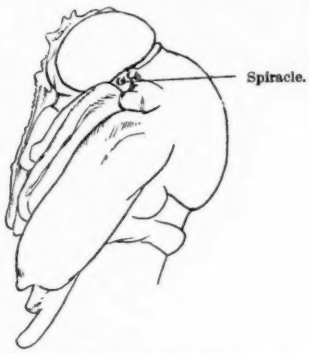


FIG. 9.—Prothoracic spiracle. Thorax of pupa, *Lampromyia sericea* Westw.

which is but imperfectly divided, and is counted as one. Two lighter brown tergites cover scutellum and metanotum; sternites are wanting for these segments, which are covered ventrally by the sheaths of wings and legs. The first six segments show at each side a long and sharp spine, and nearer to the hind margin lies a spiracle, below which is a longitudinal row of shorter and smaller spines. The anal end of the last segment has two strong, ventrally turned hooks, which are always hidden in the adhering larval skin. This bursts in the dorsal median line of the thoracic segments,

so that the head-capsule and the whole larval skin are preserved with each pupa.

The whole surface, and especially that of the abdomen, is covered by innumerable sand-grains which are glued to it by a secretion. The integument of the inter-segmental parts of the abdomen is transversally rugose; that of the segments shows densely set, minute spines, all directed anally.

The prothoracic spiracles and those of the abdominal segments are, as in the larva, of different construction.

Both spiracles are almost of the same size, for the pupa is always hidden in the sand, but the first is embedded in the strongly chitinized walls of the thorax, while the abdominal one stands on a flat cone. The stigmatic plate of the prothoracic spiracle has a strongly chitinized margin, and shows three to four stigmatic openings. The stigmatic scar lies anally, and a strong muscle, directed head-wards, remains preserved even in the cast

FIG. 10.—*Lampromyia sericea* Westw. Prothoracic spiracle of pupa.

FIG. 11.—*Lampromyia sericea* Westw. Abdominal spiracle of pupa.

pupal skin. The plate of the abdominal spiracle is less chitinized, shows six to eight stigmatic openings, and its short trachea originates from one of the two great lateral longitudinal stems. The stigmatic scar is directed towards the median line of the abdomen.

II. Larva and Pupa of HYPERECHIA NIGRIPENNIS Wied. (*Diptera: Asilidae*).

This fly belongs to the subfamily *Laphriinae* of the Asilids. The larvae of this family have been recently treated by D. Melin (Zoologiska Bidrag, Uppsala, vol. viii, 1923), and I must refer to this paper, for all other descriptions are less detailed or wholly insufficient.

The larvae of *Hyperechia* (I have received from Dr. Brauns of Willowmore four larvae and one pupa) live in the galleries made by the carpenter-bee, *Xylocopa caffra*, to the female of which the imago of the fly bears a striking resemblance.

Few exotic larvae of the subfamily *Laphriinae* are known at all. Greene, C. T. (Proc. Entom. Soc., Washington, vol. xix, 1917), has described the

larva of the American species *Dasyllis fulvithorax* Fabr., a genus closely allied to *Laphria*.

Grünberg (Deutsch. Entom. Zeitschr., 1907, p. 524) suggests, purely on the strength of the resemblance which some imaginal *Hyperechia* bear to certain *Xylocopa*, that the larvae of the Laphriids live parasitically in the galleries of these bees. All the known larvae of *Laphriinae* live in wood infested and destroyed by other larvae—generally by those of Coleoptera (*Cerambycidae* and *Lamellicornia*), with the exception of *Hyperechia*, which seems to be specialised for *Xylocopa*; and all these dipterous larvae were formerly considered to be carnivorous. Melin now states (*loc. cit.*, p. 263) that this is not always the case. After some years of observation this author found (p. 265) that "the larvae of the robber-flies were not dependent on any carnivorous feeding, yet it was not equally certain, of course, that they really avoid such food."

Further, Melin found that our Palaearctic Laphriine larvae form two different groups, of which the more robust group has only rudimentary lateral warts, and a more or less insignificant terminal plate (*loc. cit.*, p. 144).

I can state that the larva of *Hyperechia* belongs to the more robust group, as we will see later on. Melin has also stated that Hermann's groups of *Laphria sensu lat.* (proposed in Entom. Mitteil., Bd. iii, Nr. 3, p. 84. 1914) are correct. The slender forms of larvae belong to the subgenus *Epholkiolaphria* Herm. (1914), while the robust ones correspond to *Laphria sensu stricto* and its allies.

Description of Larva.

The total length of the larva is 36·5 to 37·25 mm., and the greatest width, measured on the third segment, is 8 mm. The body is almost round in cross-section and of ivory-white colour, only the dorsal plate of the head and the mouth-parts are dark brown and consistently densely chitinized (fig. 12).

The body consists of 1 (head) +10 segments. The skin shows no traces of hairs, except some weak ones on the head and one at each side of the papillae on the last segment. From first to ninth segment each tergite is provided laterally with a large round callosity, beneath which is a smaller one. Ventrally the fourth to ninth sternites show a pair of contractile processes (Melin, Kriechschwielen). The tenth segment is composed of two segments, more or less fused together (Melin, *loc. cit.*, p. 117). The two sections of this segment are here marked dorsally by a transverse fold, which may cover the posterior spiracles. The last section is ventrally abbreviated, and terminates dorsally in two papillae (Nachschieber), anteriorly to which is placed a single weak and short bristle on each side.

No terminal (chitinized) plate is to be found, and the dorsal sculpture is as little pronounced as in the first three segments. Melin's figures 129 and 130 (*loc. cit.*, p. 137) agree very well with our larva, except for the head and anal end. The hind margin of the first segment bears laterally a spiracle situated on the dorsal part of the lateral callosity. The hind pair of

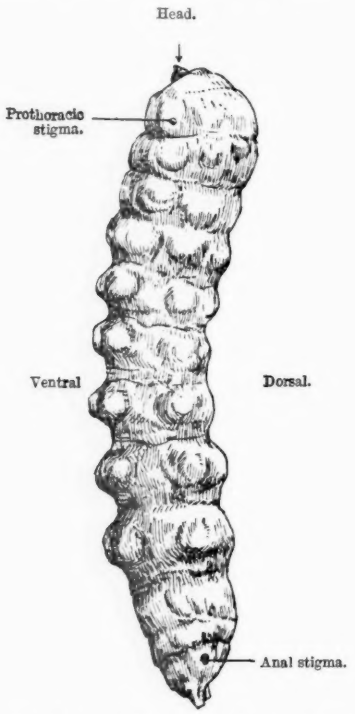


FIG. 12.—Larva of *Hyperechia nigripennis* Wied.

spiracles are placed dorsally *behind* the transverse swelling which indicates the division of the tenth segment.

Melin speaks (*loc. cit.*, p. 289) of "*ten* pairs of spiracles, of which two —placed respectively on the prothorax and the anterior section of the last abdominal segment—are considerably larger than the others. Whether these last—which are so difficult to see that they have been discovered only by Malloch and Greene—function at all I do not venture to express an opinion, inasmuch as, like the authors mentioned, I have not investigated them in detail."

I suppose that these *ten* pairs of spiracles belong to a *former stage* of the larva, of which the *last stage* only is really amphipneustic. In the

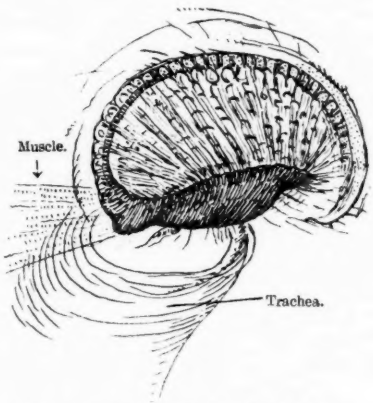


FIG. 13.—Anterior spiracle of larva, *Hyperechia nigripennis* Wied.

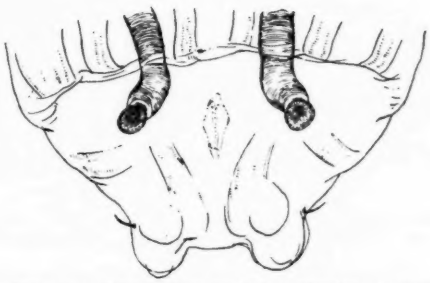


FIG. 14.—Dorsal view, posterior spiracles. Larva of *Hyperechia nigripennis* Wied.

Hyperechia larvae I found no traces of such spiracles, and my larvae appear to be in their last stage, judging by their size.

Anterior (prothoracic) and posterior spiracles are of the same structure; they belong to the multiphorous type (of Melin and Schiödte), and differ

FIG. 15.—Mouth-parts of *Hyperechia* larva. Dorsal view.

FIG. 16.—Head of larva of *Hyperechia nigripennis* Wied. Lateral ventral view.

only in the size and form of their respective spiracular plates, which are of a semicircular form in the anterior pair, and of a circular one in the posterior spiracles (figs. 13 and 14).

The study of the consistently chitinized mouth-parts was extremely difficult, for only two specimens could be dissected, and these had apparently

suffered in the formalin solution. A very slightly chitinized head-capsule is present. It is open ventrally, and is three times as long as its anterior part is broad. The strong mandibular hooks are attached to a well chitinized dorsal half-ring; they have between them dorsally a pointed labrum and ventrally a large mouth aperture. No maxillae and no maxillary palpus present. I tried bleaching with diaphanol, but could see no more parts than are shown in figs. 15 and 16.

Description of Pupa.

From one specimen: Length (including spines of head and anal end), 23·5 mm.; greatest breadth (measured ventrally in the middle of the

Fig. 17.—Pupa of *Hyperechia nigripennis* Wied.

wings), 6·5 mm. The head bears the following spines at each side: one large, on vertex; a pair of medium size on upper interior margin of eye, these forming the topmost crest. Below them at a certain distance is a small one, and on the same line with this is situated a still smaller one, immediately beneath the interior lower margin of eye. All consistently chitinized, and of dark brown colour, their tips curved downwards. A

single small spine is placed on a callosity at the base of the sheath of the proboscis.

On the anterior margin of the prothorax, and immediately below the posterior margin of the eye, is situated the anterior (prothoracic) spiracle, surrounded by a fold which ends dorsally in a flat spine (fig. 19). A small

FIG. 18.—Lateral view of pupai thorax, *Hyperechia nigripennis* Wied.

spine is situated on the first coxa, and of others, somewhat stronger ones are to be seen—one at the base of the wing, and two at the point where the two main stems of the wing-venation deviate from each other.

The first seven of the eight abdominal segments of the pupa bear a pair of spiracles on the anterior half of the lateral processes. Prothoracic and

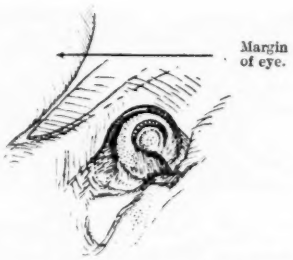


FIG. 19.—Prothoracic spiracle of pupa, *Hyperechia nigripennis* Wied.

FIG. 20.—Abdominal spiracle of pupa.

abdominal spiracles belong to the multiphorous type, and differ only with respect to their surrounding folds, which open anally in the anterior (prothoracic) pair, while in all the others the fold is interrupted in the anterior part—in the direction facing towards the head (fig. 20).

All the abdominal segments of the pupa, except the last one, are surrounded by girdles of short and spine-like bristles, which are longest on the

lateral processes. The following table will show their number and distribution :—

I. On Sternites.

A. On lateral processes.	B. Rows of short bristles on median part.
1. Segment—4–5 bristles.	1. Segment covered here by sheaths of wings.
2. ,, 7–9 ,,	2. ,, 4 bristles.
3. ,, 8–10 ,,	3. ,, 15 ,,
4. ,, 11–12 ,,	4. ,,
5. ,, 13 ,,	5. ,,
6. ,, 10 ,,	6. ,,
7. ,, 8–9 ,,	7. ,, 10 ,,

II. On Tergites.

Median rows which are placed in the same line as those on sternites.

1. Segment—14–14 bristles at each side of median line.
2–7. ,, 25–25 ,, ,, ,, ,,

The last segment shows six strong and short spines on its first division. The anal end has four curved and short hooks, of which the ventral pair is longest.